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AN EVALUATION OF THE SHIP II TOTAL SHIP  
SIMULATION MODEL

Robert N. Harris

Naval Personnel Research and Development  
Laboratory

June 1973

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EVALUATION OF THE SHIP II  
TOTAL SHIP SIMULATION MODEL

Work Unit No.  
(TDP 43.07X.B2.33W)

Robert N. Harris

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## FOREWORD

This investigation was performed in support of Advanced Development Objective 43.07X, Manpower Effectiveness which states a requirement for Simulation Models for Ships, aircraft, submarine units, and shore activities, to permit full consideration of trade-offs between manpower and other significant parameters in an operational environment.

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13. ABSTRACT <p>The purpose of this report was to evaluate SHIP II, a total ship manpower simulation model developed under advanced development funding. All previous research applications were first reviewed. The data were then used to evaluate the model in terms of a comprehensive set of model evaluation criteria which included validity (predictive and construct), sensitivity, reliability, utility, and practicality. The utility of SHIP II was found to be good; SHIP II can be used to study many types of manpower problems and, for some problems, can provide data not available from other sources. The practicality of SHIP II is low mainly because SHIP II requires a large amount of input data and is costly to operate. The construct validity of SHIP II was found to be satisfactory. The data was not sufficient to evaluate the model in terms of predictive validity, reliability and sensitivity. SHIP II has high enough potential utility to the Navy that further work to investigate the validity, sensitivity and reliability of the model would be worthwhile, especially if it appears that SHIP II would be accepted by Navy manpower planners.</p>			



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## SUMMARY

### Problem

SHIP II is a computer simulation model of a shipboard manpower system undergoing advanced development. Although the model has been used in a series of shipboard manpower studies which have produced significant findings, Navy manpower planners have not been receptive to its use as an operational model for solving shipboard manning problems. Such reluctance is based in part on the fact that data on the quality and utility have not been readily available. This report will provide a comprehensive evaluation of SHIP II quality and utility together with discussion of factors affecting the future use of the model.

### Background and Requirements

SHIP II has been supported under Advanced Development funding (TDP P43 07X). The funding used for this sub-project will be terminated on 30 June 1973. A requirement therefore exists to summarize that ADO subproject in terms of the quality and utility of the model which has resulted from it.

### Approach

The evaluation of SHIP II was performed in the following steps:

1. A set of model evaluation criteria was developed, based on the model evaluation literature.
2. Each study using SHIP II was described.
3. The data from each study was evaluated in terms of its implications for each of the evaluation criteria.
4. The study results were summarized to obtain judgments of the overall adequacy of SHIP II with respect to each criterion.

### Findings

1. No major face validity problems were found, but the study data were insufficient to provide a complete evaluation of SHIP II validity. Face validity was used because of the absence of SHIP II predictive validity data.

2. Construct validity of the model is satisfactory.

3. Sensitivity is adequate except possibly for two input variables studied. But data for only part of the input-output variable combinations of SHIP II were available for evaluation.

4. The data from the studies were not sufficient to evaluate SHIP II reliability.

5. The utility of SHIP II is very good. SHIP II is applicable to a variety of Navy manpower problems.

6. The practicality of SHIP II is low but roughly equal to other models of similar size.

### Conclusions

1. SHIP II has the potential to provide significant assistance to Navy manpower planners which is not available from existing methods. The types of problems which SHIP II can study make SHIP II a potentially valuable addition to Navy manpower study methodology. Few other models similar to SHIP II exist, and none provide the versatility which is characteristic of SHIP II.

2. The potential of SHIP II cannot be fully used because the technical characteristics of the model are still not completely known. Of the five major criteria used, the data for only two and part of a third were sufficient to provide an adequate evaluation of SHIP II. The predictive validity, reliability and sensitivity of SHIP II are still largely unknown.

### Recommendations

1. The Navy manpower planning community should be informed about how SHIP II can potentially be of assistance in the study of ship manpower problems. (p. 99-114)

2. Further evaluation studies of SHIP II would be worthwhile if SHIP II would receive significant recognition by Navy manpower planners. (p. 99-114)

3. SHIP II should be transferred to the newly established Navy Personnel Research and Development Center for performance of the additional evaluation studies. (p. 99-114)

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## I. INTRODUCTION

### A. Problem

The total Ship Simulation Model (Ship II) has been under development since May 1969 and has been successfully applied to two classes of Navy Destroyers.<sup>1</sup> Since Ship II has the potential of dealing with a diversified array of input and output variables in much greater depth than any other known model, it represents a valuable addition to the manpower planning process. Notwithstanding these operational applications of the model, the potential usefulness of the model has not been fully appreciated and, in fact, is not well known. Manpower planners do not have enough information about Ship II model quality and uses to effectively apply the model to their problems. In view of the considerable resources spent to develop Ship II, a critical evaluation of its utility in assisting manpower planners is necessary. The results of this evaluation are presented in this report.

### B. Objectives

The first objective of this report is to draw together all research results on Ship II into an integrated and comprehensive statement of the quality of the model. The information on model quality is intended to be used in two ways: (1) To evaluate the benefits which can be obtained from Ship II in light of its development costs, (2) To assist personnel who have manpower problems to solve and want to determine if SHIP II will meet their needs.

The second objective is to present enough information for a user to determine if Ship II can be used for his particular area of application. This type of information includes mainly detailed descriptions of model input data requirements and output data types and formats. This information is not intended to be sufficient for the reader to understand how the model operates; the intent is to provide enough information for a potential user to determine whether the use of Ship II is appropriate and feasible for his application.

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1 The two classes of destroyers to which Ship II has been applied are the DDG-2 and the DD 963. Chapter II summarizes these applications.

## C. Background

### 1. History of Ship II Development

In June 1967, after a successful application of the COSIMO simulation model by the New Developments Research Branch (1966), the Bureau of Naval Personnel (Pers-A33) initiated exploratory development research (EDR) concerned with the development of a Total Ship Simulation Model (TSSM). The purpose of the research was to test the feasibility of developing a simulation model of an entire ship so that personnel research could be performed at the total system level. A simulation advisory group, composed of representatives of various Navy organizations was formed to provide guidance to the effort.

The EDR was completed in June 1968 and was reviewed by the advisory group. The results of the review, despite a variety of cautions concerning cost, scope and validity, were generally favorable and plans were made to continue the research into the advanced development phase. These plans provided for model improvement, data refinement and the training of Navy personnel in the use of the TSSM.

By April 1969, following refinement of the data base, the first analytic study (Spencer, Lichtenberg, Hass and Byrnes, 1969) was performed. Immediately following the application, the model was reprogrammed and the second generation model (Ship II) emerged. Ship II has since been modified and improved many times.

Ship II has also been applied by NAVPERSRANDLAB to several types of problems for the purpose of both obtaining data to evaluate the model and to assist in the solution of real problems for Navy manpower planners.

These studies using Ship II have been conducted under Advanced Development funding (TDP P43 07X). The purpose of ADO funding was to test the feasibility of Ship II as an operational manpower planning tool. Ship II has been under development for a sufficient length of time that its utility and suitability for this purpose should be evaluated. ADO funding for Ship II will be terminated on 30 June 1973.

### 2. Description of Ship II

a. General Description: Ship II is an event-advance,

stochastic simulation model; it uses manning, equipment and task data inputs; generates performance times from distributions, and accounts for personnel utilization, task performance, and equipment readiness. The model contains an elaborate personnel assignment logic which attempts to match personnel to jobs or watch stations with a minimum of queuing. This is done by employing, when necessary, relief watchstanders, upward absorption of work (assigning jobs to skill levels higher than required when the specified skill is not available) and/or equivalent NECS. The detailed personnel record together with the flexible assignment logic are important features of the model. During a simulation run, many of the functions will be active simultaneously; in some cases conflicts occur. For example, if the employment schedule calls for a GQ exercise, all hands will be required to man stations and, therefore, other work must stop. The model handles conflicts such as this by allowing jobs to be interrupted and resumed at a later time when the personnel become available. Throughout the simulation, statistics are maintained on each type of activity. Data are also maintained on the readiness of the ship to perform mission functions, including equipment readiness and training readiness.<sup>2</sup>

Ship II is basically a resource allocation model in which the limited resource to be allocated is the ships crew and it's time. There are many different types of demands which are placed on the crew which conflict in time requirements, priorities, skill requirements, etc. Basically, SHIP II is a device for keeping track of the resolution of these conflicting demands in terms of:

- (1) Workload for each crew member in 9 types of activities
- (2) Task completion (maintenance tasks, ships work, etc.)
- (3) Equipment state and
- (4) Ships readiness

Ship II incorporates many real world dynamic interactions which cannot be included in analytic models. For example, a requirement may exist for a job to be done and some personnel required to do the job may be idle, however, the job may not get done because a member of the team is engaged in a higher priority activity. The output statistics would then show a job queue at the same time that it shows

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<sup>3</sup> This paragraph is taken from Hutchins, Prather, Barefoot and Flint (1973), p. A-475.

personnel idle.

The requirement for corrective maintenance occurs when an equipment failure is found. Equipment failures are generated using failure rates and equipment operating times to determine when the malfunction occurs. When a malfunction is found, a failure is designated and is sent to the troubleshooting function for fault isolation and then to the repair function for repair and verification. Whenever an equipment failure occurs in a mission oriented equipment item, a readiness decision table is used to make the appropriate alteration in the readiness of the associated subsystem and of the total ship.

The model is designed so that every individual in the crew is identified separately and uniquely. Each man is given an identification number, rating, rate, and NEC, when appropriate. In addition, Ship II keeps track of each man so that his status is always known.

The model incorporates an elaborate personnel assignment logic which matches personnel to jobs and watch stations. Some of the techniques used to obtain men for assignments are use of relief watchstanders, assignment of jobs to skill levels higher than required when to specified skill is not available, and using equivalent NEC's. Ship II follows certain rules in job assignment which can be varied by the user. Given these rules, Ship II then assigns men dynamically, interrupting lower priority jobs to assign men to higher priority jobs, relieving men from jobs so they can stand watch, etc.

During a simulation run, many of the shipboard functions will be going simultaneously. If conflicts occur, Ship II handles these by allowing jobs to be interrupted by higher priority activities and resumed at a later time as personnel become reavailable. This interrupt function occurs, for example, during a General Quarters exercise, when all hands are required to man watch stations.

b. Basic Model Operation<sup>3</sup>: In Ship II the control and processing of chronological events is dependent on the use of a "master clock" or simply "clock." At the beginning, the "clock" is set to zero and moved ahead depending on the occurrence of events or functions. The clock has no real-time meaning in that a simulation which lasts

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3 This section is based on Smith, Spencer and Brooks (1970).

a few minutes on the computer may have simulated many days of system activity. Because the program controls the time of simulation via the "clock," it is also possible to simulate simultaneous events merely by not changing time while these events are taking place.

Ship II is an event advance (Emshoff and Sisson, 1970) model. In this type of model, the program moves the master clock ahead just far enough to reach the next event and then exercises the associated logic. Since each event has a time associated with it, the program need only check the time of the list of events to find event with the lowest time value. The event (or events) associated with this minimum time is called the imminent event. In this way the program moves time ahead at uneven intervals. In some cases when events occur at nearly the same time, the movements in time may be very short; at other times, e.g., between 12:00 and 4:00 a.m., events may be rare and the time steps may be in hours.

In some cases it is not possible to determine the next time at which an event will occur. For example, if the event is an equipment failure and repair cannot be started due to the unavailability of personnel (they are occupied elsewhere), it is not feasible to attempt to determine when the personnel will become available. Therefore, the event will be classified as delayed and the program will attempt to process it at each successive imminent event. That is, each time the clock is moved, the program will check for delayed events (identified by a special flag) and if any exist, it will attempt to initiate them.

Events which occur in the model are processed by subroutines which represent system functions. The system functions which represent functions performed onboard ships will be discussed in Section III-B-1. Events are processed in the model by the use of transactions which are contained in a transaction table. This table contains the data about each event, such as its type, the time of its occurrence, the function or subroutine it is currently "in" and the next function which will occur next. When an event becomes imminent, the master program uses the data in the transaction table to determine what subroutines should be used to process it.

Resources, such as personnel, which are required to perform a function are made unavailable to other events when the event transaction enters a function. These resources

are not released until the function has been completed (e.g., the simulation clock has moved to the time at which the transaction is scheduled to leave the function). In some cases, higher priority demands may interrupt an activity, in which case the resources are released immediately.

## II. REVIEW OF SHIP II STUDIES

### A. DDG-2 Reduced Manning Study (Schwartz, Parker and Rhodes, 1970).

#### 1. Study Description

This study was done to evaluate the impact of a general across-the-board reduction in the crew of a guided missile destroyer (DDG) on ship operations, personnel workload and ship readiness. The normal ships allowance of 319 men was taken as the baseline against which to compare the reduced manning. The reduced complement totaled 267 men and was developed from an enlisted distribution plan provided by OPNAV. The 267 men represents a reduction of approximately 16%. Two simulation runs of 10 weeks each were used for each of the two conditions (baseline manning and reduced manning). This is equivalent to two replications, each of sample size 10, for each condition.

The following changes were made in the billets allotted to each division of the DDG-2:

#### N Division

##### Deletions:

Ships Personnel Clerk (1)

#### OC Division

##### Deletions:

Electronic Communication Tech (1)  
Radar Tech (1)  
Radarman (10)

##### Additions:

Radarman Apprentice (2)

#### OE Division

##### Additions:

Electronics Tech (1)

#### 2nd Division

##### Deletions:



Missile Ordinance Tech (1)  
Gun Ordinance Tech (2)

Additions:

Gun Ordinance Trainee (1)

F Division

Deletions:

Fire Control Tech (1)  
Apprentice Fire Control Tech (6)

F-2 Division

No Changes

1st Division

Deletions:

Boatswains Mate (2)  
Apprentice Boatswains Mate (3)  
Facilities Maintenceman (1)

M Division

Deletions:

Assistant Propulsion Supervisor (2)  
Propulsion Machine Operator (3)  
Propulsion Machine T/E (1)

B Division

Deletions:

Ass't Steam System Supervisor (1)  
Steam System Operator (1)  
Apprentice Steam System Operator (1)  
Steam System Trainee (1)

R Division

No change

S Division

Deletions:

Supply Accountant (1)  
Storekeeper (1)  
Storekeeper Apprentice (1)  
Pay Records Adm. Apprentice (1)  
Ships Storeman (1)  
Ships Laundryman (1)  
Ships Cook (1)  
Apprentice Cook (2)  
Food Service Trainee

## 2. Findings

Reducing the crew size by 16% led to slight increases in personnel workload and a marked inability to accomplish the scheduled daily work requirements. Most of the high priority tasks (i.e., corrective maintenance, evolution) were accomplished but some personnel were highly overworked. Delays in repair and troubleshooting were frequent and there was a moderate decrease in division training. Large amounts of facilities maintenance, and support and administrative work, both low priority tasks, were not done under the reduced manning. The results showed that a ship operating under the reduced manning could operate properly for a short time but ship readiness would probably decrease over a long period of time. This study showed that Ship II is useful for study of manning reduction problems.

A detailed description of the findings is contained in Schwartz, et. al. (1970), Appendix B. The findings of the study are summarized in Tables 4 and 12.

### B. DDG-2 Sensitivity Analysis (Schwartz, Parker and Rhodes, 1970)

#### 1. Study Description

This study was done to determine how selected output variables of the model responded to changes in independent variables associated with equipment maintenance and ships work. This study was one of the first attempts to do sensitivity testing of the model.

The purpose of this study was to compare responses of 15 output variables (including planned and corrective maintenance, manhours, queues and length of time in queues, readiness, cancelled work, etc.) resulting from changes in equipment reliability (mean time between failures) and repair and troubleshooting task times (Time-in-Function). The mean time between

failure (MTBF) and time in function (TIF) values were varied using Parametric Variation Ratios (See Section III-F). Four values of each input variable were used, a baseline value plus three variations from baseline. For MTBF, the variations from baseline were 20%, 40% and 60% increase in MTBF for all equipment items of the ship. TIF variations were 20%, 40% and 60% decreases in TIF values. For each the four conditions of each variable, two replications of a 10 weeks each were run.

## 2. Findings

The effect of variation in TBF and the TIF was small as measured by the changes in the 15 model output variables studied. Variability of tempo of operation appeared to exceed the influence of changes in TBF and TIF. The result of varying TIF is possibly more evident when presented graphically, but none of the differences between BL, TBF and TIF conditions were statistically significant at the 0.1 level. The lack of practical and/or statistical differences in this analysis could result from a model which is insensitive, a poor choice of parameters to vary, a choice of unsuitable output data categories to study, or too small of a sample size.

Schwartz, et.al. (1970), Appendix C, contains a detailed description of the study outputs. Tables 6, 7, 14 and 15 summarize the findings from this study.

## C. Ship II Scenario Study (Schwartz, 1971)

### 1. Study Description

All previous applications of Ship II had been total ship simulations; i.e. they used all ship divisions. The independent variables in these studies were varied within only a small part of their total range. This study was based on recognition of a need for more quantitative and sophisticated evaluation of the response characteristics of Ship II. The study was also intended to demonstrate the potential utility of Ship II to Navy manpower planners.

Specifically the objectives of the study were:

a. To test the applicability of Ship II to a ship division rather than a total ship, using a smaller data set with greater detail. The ASW Division of a DD 963 destroyer was used.

b. To study the sensitivity of a number of output measures to systematic changes in the input variable "Scenario Load." Scenario load is defined as the time spent in evolutions, training exercises, and Condition I.

Four levels of Scenario load were used:

1. No load - Readiness Condition IV.

For this condition no external operational requirements were imposed on the ship. Only Condition IV watch stations were manned. All internal requirements (ships work, division training, etc.) were scheduled.

2. Low load - Readiness Condition IV.

A low load scenario was designed in cooperation with the DD 963 Project Office. The average scenario load hours programmed was 12.96 hours/week, or 44% of the wartime load (Scenario 4).

3. Normal Peacetime - Readiness Condition IV.

The normal peacetime scenario, developed with the aid of the Project Office, included 21.63 hours/week of scenario events (73% of the wartime scenario load).

4. Wartime load - Readiness Condition III.

For this condition a combat scenario, including enemy engagements, was developed. The average scenario load was 29.50 hours/week.

Each scenario was a run for five replications of each of size 10 weeks.

2. Findings

Of the 34 dependent variables used (representing workload, watch hours, division training, evolution, PM, CM, FM and SA) all but five were found to be sensitive to variation in scenario load. In addition, the direction of change in most of the dependent variables was consistent with the expectations of the experimenters. For a detailed presentation of output variables, consult Schwartz (1971). A summary of the study findings is contained in Tables 5 and 13.

#### D. NEC Reduction Study (Schwartz, 1971)

##### 1. Study Description

In this study, the independent variable was number of persons in the ASW Division qualified (via Naval Enlisted Classifications (NEC)) to perform a set of maintenance tasks associated with the AN/SQS-26 CX Sonar System. The total number of ASW Division personnel remained the same but their qualifications were changed, i.e., four 0483 NEC's were deleted. The scenario was the Wartime Scenario, used in the previous study (Study C).

Five dependent variables were studied: Total workload for watchstanders, non-watchstanders and total division, number of PM jobs cancelled per week and ships work manhours remaining undone per week. Each of the two levels of the independent variable was run for 5 replications of 10 weeks each.

##### 2. Findings

The reduction in number of men with NEC of 0483 had no statistical or practical significance as measured by values of the five dependent variables. Given that the reliability estimates of equipments (AN/SQS-26CX) are accurate, it is reasonable to assume no degradation in capability or ability to maintain equipment would result from having five vice nine maintenance men with NEC 0483 aboard the DD 963. This study further demonstrated the utility of Ship II.

For more details of this study, consult Schwartz 1971, Appendix E.

#### E. Personnel-Workload Two Factor Study (Schwartz and Harris, 1972)

##### 1. Study Description

Previous applications of Ship II had focused on the relationships between output (dependent) variables and single input (independent) variables. Yet one of the major reasons for using simulation modeling is to study the effects of interactions between independent variables, which are not easily represented analytically. This study was the first attempt to consider the effects of simultaneous variations of Ship II independent variables.

The specific problem addressed in the study was to

explore the relative effects of variations in manpower level and imposed workload demand upon workload and task accomplishment. Manpower level and workload demand thus comprised the two independent variables used in the study. Five levels were defined for each variable, resulting in 25 combinations of values. A single replication of 5 weeks in length was run for each of the 25 values of the independent variables.

Manpower level was defined as the total number of 2nd and 3rd class Sonar Technicians (STG) in the ASW Division of the DD963. The five levels for this variable were 6,5,4,3,2, Sonar Technicians. Workload demand was defined as the total FM and S/A workload imposed on the STGs. The levels for this factor were 100%, 80%, 60%, 40%, and 20% of the FM and S/A workload specified in the DD963 Ship Manning Document.

## 2. Findings

Six of the 15 dependent variables were sensitive to variation in Manpower level and 9 were not sensitive. For workload level, this variable was not expected to have any effect on 12 of the independent-dependent variable relationships. The other three dependent variables were found to be sensitive.

Judgements were made for each dependent-independent variable combination as to whether the results obtained were consistent with the expectations of the experimenters. Twenty-eight such combinations were defined. For 13 of these combinations, the data were judged to be inconclusive. Of the remaining 15 combinations, 12 were judged to lend support for model validity and three were judged not to support model validity. A detailed presentation of study outputs is contained in Schwartz and Harris, (1972). The results of this study are summarized in Tables 8, 9, 16 and 17.

## F. DD-963 Reduced Manning Study (Rhodes, 1972)

### 1. Study Description

The possibility of an all volunteer Armed Forces has caused Navy manpower planners to consider the prospect of a significantly reduced personnel pool. Analysts must assess the impact of personnel reduction and plan ways to meet the service and operational requirements with the reduced number of men. One possible way to reduce shipboard manning requirement is to move some shipboard functions ashore, where

they might be performed more efficiently. Ship II has been proposed as a way to evaluate this possibility. A set of simulation runs could provide data to assess the effects of reduced task requirements on manpower utilization and the effects of reduced manning on task performance.

A three part iterative method was used in the study.

1. A baseline run established the statistics on manning and workload for the ship as currently manned.

2. A reduced task run produced the statistics describing workload and task performance based on full manning but with a selected set of tasks removed. Presumably, individual workload level for certain crewmen would decrease since the work requirements decreased.

3. A reduced manning-reduced task run produced statistics describing workload and task performance with both manpower and task requirements reduced. The statistics were then evaluated to determine if the reduced crew can accomplish the remaining tasks adequately.

The study was done with the S Division of a DD-963. After the baseline run it was decided that 64 ships work tasks, totalling 316 hours per week could be performed more efficiently ashore. The deleted tasks were primarily of the following types: administrative paper work, baking, ship's store, laundry, barber and disbursing.

After Ship II was run with these tasks eliminated, it was determined that 8 men could be removed from the ship. The remaining tasks which were assigned to these men were assigned to other remaining men. The simulation was then run with both reduced tasks and reduced manning. Three criteria were used to evaluate the reduced manning: (1) All watch stations must be manned, (2) task can be performed by higher rated men than originally assigned but not by lower rated men, (3) Average workload level under reduced manning - reduced task conditions should approximate the level under full manning-full tasks.

## 2. Findings

All three criteria were satisfied by the reduced task-reduced manning run. The study showed the S Division could operate with 8 fewer men if 64 of the 149 ships work tasks are

moved ashore. The study also demonstrated that Ship II is a good tool to use in gathering data necessary to evaluate manning reduction proposals. Rhodes (1972) contains detailed presentation of the data. Tables 10 and 18 contain summaries of study findings.



### III. EVALUATION OF SHIP II

#### A. Evaluation Criteria

One of the problems in evaluating a computer simulation models to select the set of criteria to be used. The criteria used in this paper are based on three studies which have attempted to specify an integrated model evaluation criteria set (Meister, 1971; Rhodes, 1970; and Hutchins, Prather, Barefoot & Flint, 1973). The criteria will be listed and defined here; a brief discussion of each criteria is contained in Sections B through G, along with the findings relating to each criteria.

##### 1. Validity

Two types of validity will be considered: construct validity and face validity. Face validity is a form of predictive validity which will be used because of the lack of data on Ship II predictive validity. The purpose of both types of validity is to indicate the correspondence of model outputs with real world data. Construct validity involves a comparison between real world process and the fidelity with which the processes are represented in the model.

##### 2. Reliability

Two aspects of this criterion will be discussed. The first is the ability of the model to produce consistent outputs when applied to similar problems by different users. The other aspect of reliability relates to precision of model results.

##### 3. Sensitivity

Sensitivity refers to the extent to which variation in model input variables causes corresponding variation in model output variables.

##### 4. Utility

The utility of a model depends directly on the usefulness of the data produced by the model in aiding in solution of real world manpower and personnel problems.

## 5. Practicality

This criterion refers to factors which constrain or facilitate the use of a model, such as cost of using the model, input data preparation required, and other such factors.

## 6. Other Criteria

Included in this category are the criteria of System Development Applicability and Model Structure. In addition, the responses given for Ship II to a model evaluation questionnaire will be presented.

## B. Validity

### 1. Discussion of Concept

Validity is perhaps the most important criterion by which to evaluate a simulation model. Since computer simulations are intended to represent and predict real life situations, the degree to which model outputs agree with corresponding variables in the real world should be a major criteria for model evaluation.

The literature indicates that two types of validity exist: predictive and construct. Predictive validity refers to the degree of agreement between the output values produced by the model and the values of the same variables in the real world under the same or equivalent conditions. Construct validity will be defined as the degree of agreement between the processes of the model and the corresponding real world processes being modeled.

a. Predictive Validity. Proof that a model has made correct predictions is probably the most convincing evidence that a model is valid. However, a major logical problem exists when validating a model by this means. When a model has been exercised with a particular combination of values of input variables and found to be valid, the finding holds only for those and similar input variables. The fact that a model is valid for a particular combination of inputs does not guarantee that it will be valid for other combinations. In addition, even for a single input, that fact that a model output is valid for a particular value of an input variable does not guarantee that the model is valid over the entire range of values of that variable.

The situation can become even more complex when input-output relationships are considered. A complex model, such as Ship II, usually has many different input and output variables. Ship II, for example, has approximately 30 major input variables and 30 major output variables. The validation process then becomes the task of testing combinations of input and output variables against an external criteria. The impossibility of testing such combinations exhaustively with a model the size of Ship II should be immediately clear. Siegel (1973), for example, points out that "a model such as Ship II provides such a rich variety of output data that validation of the predictions of each output category represents a rather formidable and impractical task. Nevertheless, the validity concept must be included in any discussion of a model which is under consideration for use as a tool for providing the decision maker with information which will help him to reach the required decisions." (p. 5)

b. Face Validity. No predictive validity studies have been performed with Ship II. But face validity information is available. Face validity is defined by Hermann (1967) as "a surface or initial impression of a simulation's realism." (p. 221). Face validity is a degraded form of predictive validity and is based on human judgements of the degree to which model outputs correspond with reality, instead of statistical comparisons of model outputs with a criterion. Face validity is certainly no substitute for predictive validity, but in the absence of predictive validity, it does provide some information about model quality. Instead of predictive validity, Ship II will be evaluated against the criteria of face validity.

c. Construct Validity. As defined above, construct validity refers to the extent of agreement between processes of the model and the corresponding real world processes being modeled. The process by which construct validity is determined is mainly human judgement based on comparisons between the modeled functions and the functions as actually performed.

Evidence for predictive validity provides strong support for a model but, as stated above, has very limited generality to other inputs or outputs not tested. Construct validity, on the other hand, has comparatively wide generality. Construct validity provides evidence that a model will operate correctly over a wide range of inputs, outputs and combinations of inputs and outputs. A well done construct validation gives more assurance that a model will operate correctly than does a predictive validation study.

Construct validity studies are important in model validation also because of the difficulty in performing predictive validity studies. Hatch (1967), for example, feels that ".... in our experience statistical validation of simulation models is often impractical. This is true because: (1) real world data typically is unavailable, (2) the cost of collecting the necessary data and running the model is very high, (3) the various statistical techniques are often of questionable value, and (4) such exercises do not guarantee validity for untested situations. Therefore, major emphasis should be placed on validation of the model concept." (p. 177)

## 2. Ship II Validity

### a. Construct Validity.

(1) Description of Ship II. As stated in the previous section, evaluation of construct validity is based mainly on human judgement. Such an evaluation has been performed for Ship II and is reported in Section (3). However, the judgements on which construct validity was based are subjective and the rationale for the judgements was not explicitly documented. Therefore, the next section, a detailed description of shipboard functions modeled in Ship II, is intended to provide the reader with enough information to make his own rough evaluation of Ship II construct validity. The Ship II flow diagram in Figure 1 shows that the basic model functions, their input and output states, and their interrelationships. Each block diagram in Figure 1 represents a shipboard function which is included in Ship II. Section (2) contains a description of each of the functions shown in Figure 1.

### (2) Description of Ship II Functions.<sup>1</sup>

(a) Analyze Operations Requirements (ANOPREQ). The purpose of this function is to process the commands entered in the employment schedule (scenario). Each command has an execution time specified by the user and when this time arrives, this function initiates the action necessary to respond to the command, including watch changes, ship status change (sea/port) and changes in the overall readiness condition.

The scenario can specify the following types of commands:

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<sup>1</sup> Some of the material in this section is based on Smith, Spencer & Brooks (1970).



- Sea/port changes and durations;
- Evolutions;
- Training exercises;
- Imposed readiness (actual Condition III or I);
- Output reports

(b) Assign Watch (ASNWATCH). Watch and evolution station manning is based on the general readiness status of the ship and the requirement to perform exercises or evolutions. The basic readiness condition of the ship, as specified by the employment schedule, can be: (a) Condition I (General Quarters), (b) Condition III (Wartime Steaming), (c) Condition IV (Peacetime Steaming) or (d) Condition V (in-port). These basic conditions are set by assigning personnel to watch stations in accordance with input data. Watch stations are manned twenty-four hours a day by rotating the personnel.

With the exception of Condition I, each watch station has three sections and personnel work on a two or four hours on, and six or eight hours off cycle. The Navy follows the practice of "dogging" watches, which means that sections of the watch shift so that any individual will not stand the same watch every day.

Watch assignments are made using the current readiness condition and section based on time of day. This information allows the identification of the specific individuals who are to stand watch. Each man required for watchstanding is placed in the "on-watch" category at the appropriate time and those who were on watch are placed in the "idle" category at the same time. If a man is performing a job (other than an evolution)<sup>2</sup> when his watch time arrives, that job is interrupted so that he may be released to perform the evolution.

Training exercise requirements included in the employment schedule may specify augmentation to the basic watch condition and these are also handled by this function. For example, if an exercise only involves Anti-

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<sup>2</sup> evolutions are the highest priority activity in the model

Submarine Warfare (ASW) stations, the basic watch may be augmented such that only the ASW stations are manned at Condition I. Input data allows the user to specify, through personnel assignments, up to five watch augmentations for training exercises. In completing the employment schedule, the user specifies which of these exercises will occur, and specifies which stations are augmented for specific exercises.

(c) Assign Planned Maintenance (ANS PMS).

This function reviews requirements for planned maintenance and assigns required tasks to available personnel. The maintenance task load is based on the Planned Maintenance System (PMS) and covers all tasks required aboard ship with the exception of those performed during overhaul and those performed less frequently than once a year.

THE ASSIGN PLANNED MAINTENANCE function is executed daily during the course of a simulation run. The program reviews the PM table to identify PM actions that have either been delayed or are scheduled to arise within six hours after the start of the day. The workday within which PM may be scheduled is specific by input data. Daily, weekly, monthly, quarterly, semi-annual and annual PM jobs are represented individually.

When a PM job enters the function, a test is made to determine if there are any constraining conditions which prevent performance of the task. These constraining conditions are:

- (1) Certain PM tasks specified by the user are performed only in-port;
- (2) No PM tasks are performed during Condition I;
- (3) PM is assigned only during specified working hours and not on Sunday (except daily jobs); and,
- (4) If the equipment on which PM is performed is "down", the job is delayed.

If a PM action cannot be performed due to one of the above constraints, it is delayed or postponed until the following day. The delayed action is listed in a special table for subsequent processing. If, however, the PM task can be performed, this function obtains the list of required personnel (which is specified by the user) and scans the personnel



status table to locate the required personnel. A man cannot be assigned to planned maintenance unless he is either idle or performing ship's work. In addition, multi-man PM jobs cannot be started until all specified personnel are available. When personnel requirements have been met, the selected men will be moved to the PM category in the personnel status table. Once personnel have been assigned, the job is sent to PERFORM PLANNED MAINTENANCE. If the required personnel cannot be obtained, the job is delayed until they are available, or upward absorption is used if specified by input data.

(d) Perform Planned Maintenance (PERPMS). This function represents the execution of Planned Maintenance Tasks. Function execution is characterized by the time required for completion of the PM task and the probability that existing equipment failures are detected. The total performance time includes make-ready and put-away time in addition to basic task time.

When a PM job enters this function, the system being maintained is checked to determine if an undetected failure exists. If so, whether or not the failure is detected is determined using a probability value associated with the system and the type of PM action. If detection occurs, the model transfers to the troubleshooting function. If not, the PM function continues.

Since PM jobs can be interrupted and personnel reassigned to higher priority activities, such as critical corrective maintenance, watch assignments, or General Quarters, the PM function can reprocess jobs which are re-entered following completion of the interrupting activity. At the time the PM job is interrupted the system will store the remaining time to complete the PM task. The interrupted PM transaction will later be processed as a normal PM transaction and the time remaining which was stored when the job was interrupted will be used as the task time.

Since the Planned Maintenance System is designed to prevent as well as detect malfunctions, any delay or cancellation of PMS jobs may adversely affect the reliability of hardware. For future model growth capability, each PM task can be assigned a code of P, C, or B which denotes, respectively, whether the action is a task to determine the state of the equipment (P), an action which changes the state of the equipment (C) or both (B). If actions coded C or B are delayed for a significant period of time, it is likely that the equipment will degrade, resulting in an increase in the



probability of failure. Presently, the model has no provision for simulating this effect, and it is unlikely viable data on this effect will be available for some time to come.

(e) Assign Daily Facilities Maintenance and Administrative and Support Work. This function checks the time of day, the day of the week, the port or sea state, and the readiness condition to determine if the list of Facilities Maintenance (FM) and Support/Administrative (S/A) work should be scheduled. If all conditions are met, then the jobs are scheduled. If any condition is not met, scheduling is postponed to a later time. This may involve work being carried over to the next workday. FM and S/A jobs are scheduled Monday through Saturday (inclusive) while at sea, and Monday through Friday while in port.

(f) Perform Daily Facilities Maintenance and Administrative and Support Work (PERWORK). When ships work can be assigned, this function makes the detailed assignments to individuals. Before the job is assigned, this function determines how many men are required by dividing the required man hours by the time remaining in the day. Using this value, an attempt is made to assemble a team from the available personnel. When jobs will require only one man, this process is not required.

Once a job is assigned, the associated personnel are identified as performing facilities maintenance or administrative/support tasks, and are held in this category until the job is completed or interrupted. Input data allow the user to specify the use of upward absorption when not enough primary personnel are available. Also, FM and S/A jobs are assigned first to those individuals with the fewest total work hours so as to balance the workload.

(g) Schedule Divisional Training (INITRA). This term is used to describe divisional group meetings which are held for the purpose of general training. The types of subjects covered in such meetings include general orientation, Navy doctrine, leadership, and other such subjects. This function schedules classes for each of the divisions aboard ship, based on the following constraints:

(1) Divisional training is scheduled only during a specified daytime period;

(2) Classes are not scheduled on Sunday;

(3) Scheduling of classes is not attempted during an actual or exercise Condition I;

(4) If the number of personnel available for divisional training is less than the minimum specified by input data, the session is delayed (rescheduled).

Ship II also uses input data, such as minimum number of personnel required for a class, to determine whether classes can be scheduled.

If these above criteria are met, this function transfers control to the EXECUTE DIVISIONAL TRAINING for the actual assignment of personnel. If not, the model attempts to schedule training at a later time.

(h) Execute Divisional Training (DIVTRA). When the above function has established that a training session can be held, this function assigns the appropriate personnel to the class and keeps them in that status until the designated time has elapsed. Since divisional training can be interrupted by higher priority demands, this function contains the logic necessary to release personnel and resume training at a later time.

(i) Monitor Watch Station (MOWSTA). This subroutine computes the time required for detection of failures in subsystems. When failures occur, this function is entered at the time of initial failure or after a Type II error in the troubleshooting function (see section (m)). The computed detection time is based on a detection delay time (input by the user) which depends on the subsystem in which the error is present and the ship readiness condition. Since failure detection is also possible during PM, the delay time computed in MOWSTA may be reduced, to represent detection during PM. This is done by determining if a PM detection did occur and then reducing the computed detection time accordingly.

(j) Perform Evolution (PERFEVOL). Evolutions are scheduled when specified in the Employment Schedule. At this time the PEREVOL function mans the necessary stations with the personnel designated in the watch bill. This function then holds these personnel on station for the designated evolution period. When required personnel are engaged in other tasks, they are interrupted and the personnel assigned to the evolution. Following the completion of the evolution, this transaction releases the personnel.

(k) Training Exercises (PERTREX). This function executes the exercises and drills listed in the Employment Schedule. All required personnel are placed in training exercise status by ANSWATCH prior to entrance into this function. The time for completion of this function is based on input data in the Employment Schedule.

This function can be delayed if the systems required to perform an exercise (as specified by input) are not available. For example, if the user specifies that a missile fire control system is required for a tracking exercise, that exercise will not be started if the fire control system is down for repairs. Extensive delays for systems can cause the exercise to be canceled.

(l) Repair of equipment (REPAIR). This function represents the repair of a system failure. This function is entered whenever an apparent system failure has been found in an item which is repairable aboard ship. The performance of this function is characterized by resource requirements, time to complete the task and probability that the repair was performed correctly. Resource requirements are of two types: Personnel and equipment. Both are defined by the user. Personnel are specified in terms of rate, rating and NEC; equipment is specified in terms of specific equipment items needed. Performance of the repair function will be delayed whenever the specified personnel or equipment are not available. By use of upward absorption and equivalent NECs, a secondary set of personnel can be assigned if the primary set is unavailable.

Performance time is determined by Ship II by making a random draw from a log normal distribution. The mean and standard deviation of the distribution are specified by the user for each equipment. Performance time can, in addition, be affected by the occurrence of one of the two types of errors which can be made during the repair function.

A "type t" error refers to delay in completion of the repair function beyond a nominal performance time specified by the user. This type of error represents errors in performance of repair which are discovered before the repair has been completed. The effect of a "type t" error is an increase in performance time. The probability of occurrence of a "type t" error is specified by the user for each equipment.

The reliability of repair is represented by the occurrence of a "type d" error. This error represents failure to correct the malfunction or damaging another equipment component during repair. The occurrence of a "type d" error is based on a random draw from a log normal probability distribution. When a "type d" error occurs, the actual equipment state is set to "bad" while the apparent state is set to "good". If a "d" error does not occur both actual and apparent state are set to "good". The probability of occurrence of "type d" errors are specified by the user.

The Repair function can be interrupted by higher priority functions. REPAIR contains the logic required to resume performance of the function after the higher priority function has been completed. Except for repair of equipment which has been designated by the user as critical, performance of the repair function also depends on time of day, day of week and readiness condition of the ship. Repair of critical equipment, on the other hand, is done immediately regardless of conditions. Table 1 shows the factors which interact to affect the performance of non-critical repair.

One other factor affects the performance of the repair function: probability of deferral for parts. Ship II determines randomly whether deferrals occur, based on a deferral probability specified by the user. When a deferral occurs, the length of the deferral is based on a random draw from a log normal distribution. The repair function is reinitiated after this time has elapsed.

(m) Troubleshoot (TRBSHT). This function isolates the cause of malfunctions to the level necessary to determine the repair requirement; the function is initiated following the detection of a malfunction. The performance of this function is characterized by resource requirements and time to complete the job. Resource needs are specified in terms of rate, rating and NEC of personnel, and special test equipment. Resource requirements for troubleshooting each ship equipment are specified by the user. If the required resources are not available, this function will be delayed until they are. Like the repair function, this function also has the capability for upward absorption and use of equivalent NEC whenever the primary personnel are not available.

Performance time is the time between the initial assignment of resources and the point at which a conclusion has been reached as to the required corrective action,

TABLE 1

DECISION TABLE FOR PERFORMANCE OF REPAIR  
AND TROUBLESHOOTING FUNCTIONS

<u>CONDITIONS</u>	<u>Workday</u>			<u>Not Workday</u>		
	Weekday	Sat.	Sun.	Weekday	Sat.	Sun.
1. Time of day						
2. Day of week						
3. Readiness Cond.	I III IV V I III IV V I III IV V I III IV V					
<u>ACTIONS</u>						
1. Perform CM	X	X X	X	X		
2. Postpone until workday				X	X X	X X
3. Postpone until next weekday			X		X	X X
4. Postpone until change in readiness condition	X	X	X	X	X	X

excluding any interruptions. Basic performance time is determined from a log normal distribution whose parameters are specified by the user. Performance time is increased whenever a "type t" error occurs (see below). The function randomly determines if a "type t" error occurs and, if so, increases the basic performance time by a value obtained from another draw from a log normal distribution. The use of the "type t" error provides a means of incorporating the effects of functional decision errors which are discovered before the final conclusion has been reached.

Performance reliability is the percent of troubleshooting attempts which correctly isolate the source of the malfunction. The following types of errors can result from a troubleshooting action:

- TYPE I - Erroneously designating the state of a system as bad.
- TYPE II - Erroneously designating the state of a system as good.
- TYPE III - Erroneously identifying the cause of a malfunction (a combination of a Type I error and a Type II error).
- TYPE t - Delaying the conclusion of a troubleshooting action beyond some nominal performance time, input by the user.

The probabilities of each type of error are specified by the user. When the job is completed, these maintenance error probabilities are used to determine if an error has occurred. If a Type II error occurs, the program goes to function MOWSTA. If a Type III error occurs, a code is set denoting that repair will not be successful. If a Type I error occurs, the transaction is sent to REPAIR even though the equipment is actually good. If no error occurs, the transaction is sent to REPAIR if the equipment is actually bad; if the equipment is actually good, the program proceeds to the next scheduled function.

The TROUBLESHOOT function may be interrupted by higher priority demands, such as General Quarters, if a critical system is not being troubleshooted. After an interrupt has occurred, the troubleshooting function is re-entered when the personnel become available (or the readiness condition permits).

The performance of non-critical troubleshooting function depends on time of day, day of week and readiness condition in exactly the same way as does repair. Table 1 shows how these factors affect non-critical maintenance. Troubleshooting of critical equipment is done immediately regardless of conditions.

(n) Support Activity Maintenance (SUPAM). This function represents the support the ship receives when an equipment repair task is beyond its capability, due to lack of training, special equipment, or technical information. This function is characterized by the time required to receive the technical support required. This function is always entered from the TROUBLESHOOT function.

Input data provide the probability that a repair action will be deferred for assistance and the mean and standard deviation of the time for such assistance to be received. A log normal distribution is used to determine waiting time.

At the conclusion of this function, it is assumed that the repair has been finished and the operational status of the failed item is set to "good".

### (3) Estimation of Construct Validity

The construct validity of the Ship II functions summarized above has been estimated in a study performed by Schwartz, Rhodes & Parker (1970). An index of construct validity was calculated in the following manner:

(a) Each shipboard function and associated subroutines was evaluated, comparing the manner of its performance to that of the same functions either performed in the referrent system or specified by Navy doctrine. The subroutines listed in Table 2 do not directly represent shipboard functions and therefore were not described in the previous section. However, since the construct validity study did include these subroutines, the data will be reported here.

In the comparison between modeled function and shipboard performance of the function, a scale for judgement ranging from 0 to 1.0 was used scale values were assigned to represent the extent of agreement between functional performance.

TABLE 2

ESTIMATION OF SHIP II CONSTRUCT VALIDITY

<u>Function Name</u>	<u>Weight of Function W<sub>i</sub></u>	<u>Validity Estimate V<sub>i</sub></u>
1. ANOPREQ	.05	.90
2. ASNPMS	.03	.95
3. ASNWATCH	.03	.98
4. ASNWORK	.03	.85
5. DIVTRA	.04	.80
6. INITRA	.03	.80
7. MOWSTA	.03	.85
8. PERFEVOL	.04	.85
9. PERPMS	.07	.95
10. PERTREX	.04	.85
11. PERWORK	.07	.75
12. REPAIR	.09	.97
13. SUPAM	.04	.85
14. TBLSHT	.07	.97
<u>Subroutine Name</u> <sup>3</sup>		
1. GETCLASS	.03	.80
2. GETEAM/CHEKTEAM	.08	.85
3. GETGUYS/LAZYFIRS	.06	.90
4. MANANA/CARYOVER	.05	.85
5. SCORETYM	.08	.50
6. WHENDONE	.04	.80

Overall Construct Validity index  $\sum W \times V_i = .847$

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3 These subroutines do not represent shipboard functions and were not described in the previous section.



(b) The scale values were then weighted according to contribution of the corresponding function to overall model validity.

(c) A model construct validity index was then computed by summing the products of the scaled values and function weight, i.e.,  $CV = \sum V_i \times W_i$  where

CV = construct validity index

$V_i$  = Validity estimate of the  $i$ th function

$W_i$  = Relative contribution of the  $i$ th function to overall validity

The results of applying the construct validity criterion to the Ship II model functions are shown in Table 2. This table shows that the construct validity index is satisfactory.

Siegel (1973), after an independent evaluation of Ship II, agrees with this statement: "From the point of view of the internal logic of Ship II, the various algorithms appear to be at the current state-of-the-art" (p. 4).

#### (4) Construct Validation Performed During Development.<sup>4</sup>

From the very beginning of Ship II development, there was great concern that the model represent and include factors of interest to Navy planners. To insure that the modeling effort was properly responsive to Navy needs, a Simulation Advisory group was formed to provide guidance to the effort.

One of the major decisions made during the development effort was the selection of functions to be included in the model. Since the program was to simulate an entire ship for manpower research, it was decided that every shipboard function involving human performance was to be treated. These functions included the performance of watch, evolutions, exercises, division training, and the various classes of maintenance and ship's work.

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<sup>4</sup> See Section I-C.

TABLE 3

FACTORS RESPONSIBLE FOR LOWERING  
THE CONSTRUCT VALIDITY OF SHIP II

ASNWORK	attempts to schedule work on a regular basis; work is scheduled irregularly aboard ship.
DIVTRA & GETCLASS	attempt to assign all idle men to division training classes; other attendance criteria are probably significant aboard ship.
INITRA	attempts to schedule division training classes on a regular basis; classes are scheduled irregularly aboard ship.
MOWSTA	does not produce erroneous failure reports for equipments that have not actually failed.
PERFEVOL	assigns fixed teams to evolutions; assignments are more flexible aboard ship.
PERTREX	will not allow performance of exercise if required subsystems are not rated C-1; requirements are more flexible aboard ship.
PERWORK	does not assign men to jobs that are too large to complete; jobs may be partially completed aboard ship.
SUPAM	computes deferrals on a strict probability basis; various factors influence deferrals in the fleet.
GETEAM & CHEFTEAM	use rigid rules for priorities; priorities are more flexible aboard ship.
GETGUYS & LAZYFIRS	use rigid rules for selecting men to do ship's work; assignments are more flexible aboard ship.
MANANA & CARYOVER	compute work remaining and carryover by simple formula; factors affecting work carryover are more complex aboard ship.
SCORETYM	uses unrealistic, simplistic, probabilistic scoring system instead of evaluating various factors that contribute to type commander's readiness rating.
WHENDONE	allows jobs to be done at regular times; scheduling is not so regular aboard ship.

The general procedure followed in modeling ship functions was to develop a logic flow chart of the processes and activities taking place on the ship, then convert that into a computer program flow chart. Programming, key-punching and debugging then followed. The problems of model validity and verisimilitude were an important consideration in this process. Since some of the intended model uses precluded empirical validation of results, particular attention was devoted to ensuring the correspondence of program logic to real world processes. Operational fleet personnel were consulted extensively during functional design. Compromises sometimes had to be made between construct validity of the model and programming limitations. In cases where artifacts were introduced to simplify programming, they were constructed so as not to introduce non-correspondence with the real world. Real world processes not considered relevant to the model outputs were excluded.

After the original version of Ship II was developed, an extensive review of the model was conducted under the supervision of the Simulation Advisory Group. Comments were solicited from Navy personnel representing both model users and model developers. The comments resulting from this review were responded to by a revision of the model. The resulting model, which is the current version of Ship II, is more closely reflective of the real Navy world than the previous version.

In summary, the close participation of Navy experts in the development and revision of Ship II functional definition provides support for believing that the construct validity is satisfactory.

#### b. Face Validity

A summary of face validity judgements for Ship II is contained in Tables 4 through 10. The data in these tables are taken from the studies summarized in Section II. The judgements of whether or not the changes in the dependent variables appear to be realistic has been made by the authors of the individual studies rather than by the author of this report. Generally, the validity judgements are based on the direction of change in the dependent variable values. No attempt was made to judge the correctness of the magnitude of the change in dependent variables or of the form of the curve showing changes in dependent variables as a function of changes in independent variables.

Each dependent variable in the table is followed by a number in parenthesis. This number corresponds to one of the nine types of output reports discussed in Appendix B, Section B. For example, if a dependent variable is followed by (5), a definition of that dependent variable will be found in section B-5 of Appendix B. In addition, each table will be followed by a brief statement of the rationale behind the validity judgements for each dependent variable in the table.

### C. Reliability

#### 1. Discussion of Concept

The literature reviewed indicates that the term "reliability", as applied to stochastic models, includes two separate concepts. The first deals with whether different users can use the model on similar problems and obtain reasonable consistency in model results. When a model is applied to same or similar systems by various users, comparable results should be obtained. A model which produces contradictory or inconsistent results when applied to the same problem by different users would be unreliable and the results from the model could not be trusted.

The second viewpoint on reliability is that a model's reliability is simply a factor which determines how many model runs will be required to produce a given level of output precision. It is a well known statistical fact that large samples produce better estimators of population means than do small samples. In addition, confidence intervals become shorter as sample size increases. As the number of simulation runs increases, then, the resulting means values of output variables will become increasingly better estimators of the true value of these variables. The lower the reliability of model outputs, the more computer runs will be needed to achieve any specified level of precision of estimation. Thus, model output reliability directly affects the cost of using a model, when the criteria for number of replications is achievement of a given level of precision of estimation.

#### 2. Ship II Reliability

The previous discussion has presented two elements in model reliability. It would be desirable to describe Ship II in terms of both elements of reliability. But data exist only for output variance of certain outputs. With regard to the consistency criterion, Ship II has been used only by its

**TABLE 4: SUMMARY OF VALIDITY JUDGEMENTS**  
**INDEPENDENT VARIABLE: REDUCED MANNING-TOTAL SHIP<sup>5</sup>**

DEPENDENT VARIABLE	DATA IMPACT			Direction of Change in Dep. Var. as Manning Decr.
	Support Model	Not Support Model	Inconclusive	
Percent of NWW(1)				
Watchstanders	X			Incr
Non-Watchstanders	X			Incr
Planned maint. hrs (1)				
Watchstanders	X			Incr
Non-Watchstanders		X		Decr
Corr. maint. hrs(1)				
Watchstnaders	X			Incr
Non-Watchstanders		X		None
Maint. pers.-				
Q hrs (2)	X			Incr
PM-No. cancelled (5)	X			Incr
FM & S/A-hrs left (6)	X			Incr
FM & S/A- intrpts(6)	X			Decr
Div. trng.- hrs/wk (7)	X			Decr
Pcnt time at C-1 (tot ship) (9)			X	None
Tblsht Q hrs (4)	X			Incr
Repair Q hrs (4)		X		None
Trng. read.- hrs perf/hrs sched (8)			X	None

<sup>5</sup>Study A, Chapter II

**TABLE 4: RATIONALE FOR VALIDITY JUDGEMENTS**

1. Percent standard Navy Workweek.  
Reduction in manning would be expected to increase workload for the remaining men. The behavior of Ship II in this respect provides support for Model validity.
2. Planned maintenance hours.  
The expectation is that with a constant PM load, decreases in men available for PM should increase PM hours for remaining men. This finding occurred only for watchstanders. The data for non-watchstanders was judged not to support the model.
3. Corrective maintenance hours.  
A decrease in manning should increase the CM hours for remaining men. Such an increase was found for watchstanders but not for non-watchstanders.
4. Queue hours- Maintenance Personnel.  
This variable represents queues formed because maintenance personnel of the specified rate rating & NEC are not available when needed. As number of maintenance personnel are decreased, the same rate of equipment failure would increase the demand on the remaining men, thus increasing maintenance queues.
5. Planned maintenance cancellations.
6. FM & S/A hours not done.
7. FM & S/A interrupts.
8. Division training-hours/week.  
The increasing demand for CM, as indicated for the formation of CM queues, should be reflected in reduction of emphasis on lower priority tasks. Both PM, FM, and S/A are lower priority tasks. Accordingly, the increase in PM cancellations and the increase in FM and S/A hours of work not done both indicate that Ship II is behaving correctly. However, it was also found that FM and S/A interrupts decreased. According to the authors of the study, interrupts are mainly for watch standing and scenario events, which are the same for each Manning Condition. The number of interrupts would be expected to be the same for each condition. The decrease in interrupts was attributed to decrease in number of jobs assigned. The decrease in hours spent in division training which is also a lower priority activity, also supports the model.
9. Percent time at C-1 readiness status (total ship).  
The lack of effect of reducing manning on readiness status was classified as inconclusive. Without data on the effect of reduced manning on equipment failures, the proper response of readiness status cannot be determined.

10. Troubleshooting queue hours.
11. Repair queues hours.

These variables represent time waiting for troubleshooting and repair of equipment to begin after a troubleshooting or repair requirement has been identified. The expected effect of reduced manning on these queues would be an increase in availability of maintenance personnel. This finding occurred for troubleshooting but not for repair.
12. Readiness training exercises.

The expected effect of reducing personnel on performance of training exercises is not clear. This variable was classified as inconclusive.

TABLE 5: SUMMARY OF VALIDITY JUDGEMENTS

INDEPENDENT VARIABLE: SCENARIO LOAD<sup>6</sup>

DEPENDENT VARIABLE	DATA IMPACT			Direction of Change in Dep. Var. as Scen. Load Incr.
	Support Model	Not Sup- port Model	Incon- clusive	
Percent of NWW (1)				
Watchstander	X			Incr
Non-Watchstander	X			Incr
Total Workload				
Total division	X			Incr
Watchstanders	X			Incr
Non-Watchstanders	X			Incr
Watch Hrs (1)				
Total division	X			Incr
Watchstanders	X			Incr
Non-Watchstanders	X			Incr
Div. Trng. Hrs (1)				
Total division		X		Incr
Watchstanders		X		Incr
Non-Watchstanders		X		Incr
Evolution Hrs (1)				
Total division		X		Decr
Watchstanders			X	Decr
Non-Watchstander			X	Incr
Planned maint. Hrs (1)				
Total division			X	None
Watchstander		X		Incr <sup>a</sup>
Non-Watchstander			X	None
Corr. maint. Hrs (1)				
Total division			X	None
Watchstander			X	Incr
Non-Watchstander			X	None

<sup>6</sup>Study C, Chapter II



**TABLE 5: CONTINUED SUMMARY OF VALIDITY JUDGEMENTS**

**INDEPENDENT VARIABLE: SCENARIO LOAD**

DEPENDENT VARIABLE	DATA IMPACT			Direction of Change in Dep. Var. as Scen. Load Incr.
	Support Model	Not Support Model	Inconclusive	
Fac. Maint. Hrs (1)				
Total division			X	None
Watchstander	X			Decr
Non-Watchstander	X			Incr
Supp/Admin Hrs (1)				
Total division	X			Decr
Watchstanders		X		Incr
Non-Watchstander			X	Decr
PM- No. Sched (5)		X		None
PM- total manhours (5)			X	None
FM & S/A Hourse left (6)	X			Incr
PM & S/A Intrpts (6)	X			Incr
Div. Trng.- No sessions (7)		X		Incr
Div. Trng.- Attendance (7)	X			Decr
Div. Trng.- Duration (7)	X			Decr

**TABLE 5: RATIONALE FOR VALIDITY JUDGEMENTS**

1. Percent standard Navy workweek.
2. Total Workload.  
Increasing total external workload imposed on the crew should be reflected in increased work hours. The fact that both percent of SNWW and total workload increased provided support for model validity.

3. Watch hours.  
The increasing Scenario load is accomplished by increasing the hours during which the ship is on Condition III and Condition I watch. The observed increases in watch hours stood by the crew indicates the increasing the Scenario load is having the proper effect.
4. Division training hours.  
Since division training is a lower priority activity, no reason was identified why division training hours should increase as the ship moves from Condition IV to III, to I. If there was any effect at all, a decrease in hours would have been expected.
5. Evolution hours.  
The findings for this variable are somewhat difficult to interpret. Evolution is the highest priority in the model and always gets accomplished when scheduled. This reflects the priority given to evolutions aboard ships. Therefore the evolution hours for the division should have remained approximately constant, but the data show a decrease in evolution hours. The findings for watchstanders and non-watchstanders are judged to be inconclusive.
6. Planned maintenance hours.  
The findings for PM hours are confusing. Increasing scenario load should result in decrease in PM hours, or at least no change. But PM hours for watchstanders increased, a trend judged to be inconsistent with reality.
7. Corrective maintenance hours.  
Increasing watch condition from IV to III to I increases equipment operating hours and thus equipment failures would also increase. Whether these failures would be reflected in increased CM manhours is difficult to determine. Therefore the data for this variable have been classified as inconclusive.
8. FM hours.  
FM is a low priority task. FM hours would be expected to decrease as scenario load increases. However since increasing the scenario load is actually an increase in watch hour requirements, a differential for watchstanders and non-watchstanders would be expected. In Condition II, for example, FM performed by watchstanders would decrease but would increase for non-watchstanders. The data reflect this type of differential effect.

9. S/A hours.

The findings for this variable are inconsistent with the findings from FM hours/week. S/A hours for watchstanders increased as scenario load increased, a finding judged not to support the model. S/A hours/week decreased for non-watchstanders and the total division. This finding is certainly reasonable but confusing when compared with the FM data. Therefore the data for non-watchstanders has been judged inconclusive.

10. Number of PM jobs scheduled.

The number of PM jobs scheduled on board a ship would certainly decrease during Condition I watch. The model showed no such change.

11. Number of PM jobs cancelled.

The finding that PM cancellations increase is consistent with reality.

12. PM total manhours.

The finding for this variable corresponds to variable 10-number of jobs scheduled. Ship II does not decrease PM during Condition I as would be expected on board a ship.

13. FM and S/A hours not done.

14. FM and S/A interrupts.

FM and S/A are the lowest priority tasks aboard ship. Both hours of work not done and interrupts would increase during Condition III and I.

15. Division training - number of sessions.

16. Division training - attendance.

17. Division training - duration.

Division training is also a relatively low priority activity. The decrease in attendance and duration as scenario load increases is realistic but the increase in number of training sessions is not.

TABLE 6: SUMMARY OF VALIDITY JUDGEMENTS

INDEPENDENT VARIABLE: TIME IN FUNCTION<sup>7</sup>

DEPENDENT VARIABLE	DATA IMPACT			Direction of Change in Dep. Var. as TIF decreases
	Support Model	Not Support Model	Inconclusive	
Corr. maint. hrs(1)		X		None
Planned maint. hrs (1)			X	None
Maint. pers-Q hrs (2)			X	None
Pcnt time at C-1 (Aux. eng.) (9)			X	None
Pcnt time at C-1 (AAW sch & trk) (9)			X	None
Tblsht Q hrs (4)			X	None
Repair Q hrs (4)			X	None
PM- No. cancelled (5)			X	None
FM & S/A- hrs left (6)			X	None
FM & S/A intrpts (6)			X	None
Div. trng.- hrs perf/hrs sched(7)			X	None
Trng. read.- hrs perf/hrs sched(8)			X	None

<sup>7</sup>Study B, Chapter II

TABLE 6: RATIONALE FOR VALIDITY JUDGEMENTS

## 1. Corrective maintenance hours.

This variable has been classified as not supporting Ship II, but the interpretation of this variable is complex. As equipment failures increase, the hours spent in repair and troubleshooting should also have increased. The result was not statistically significant, but examination of the curves shows that a significant difference may be present on the last three weeks (8, 9, 10). The smallest difference between baseline and reduced TIF runs is 180, 120 and 200 hours for weeks 8, 9, and 10. The statistical significance of these differences cannot be determined from data reported in the study. No discussion of the rest of the dependent variables will be included. The relationship between TIF and these variables is not clear enough to judge whether the results support or do not support model validity.

**TABLE 7: SUMMARY OF VALIDITY JUDGEMENTS**

**INDEPENDENT VARIABLE: TIME BETWEEN EQUIPMENT FAILURE<sup>8</sup>**

DEPENDENT VARIABLE	DATA IMPACT			Direction of Change in Dep. Var. as MTBF Incr.
	Support Model	Not Support Model	Inconclusive	
Corr. maint. hrs (1)		X		None
Planned maint. hrs (1)			X	None
Maint. pers-Q hrs (2)			X	None
Pcnt time at C-1 Aux. eng. (9)			X	None
Pcnt time at C-1 (AAW sch & trk) (9)			X	
Tblsht Q hrs (4)			X	None
Repair Q hrs (4)			X	None
PM-No. cancelled(5)			X	None
FM & S/A-hrs left (6)			X	None
FM & S/A- hrs left (6)			X	None
Div, trng.- hrs perf/hrs sched(7)			X	None
Trng. read.- hrs perf/hrs sched(7)			X	None

<sup>8</sup> Study B, Chapter II

TABLE 7: RATIONALE FOR VALIDITY JUDGEMENTS

1. Corrective maintenance hours.  
Increases in MTBF should be reflected primarily in higher equipment failures. Corrective maintenance hours should correspondingly increase. No such effect was found. MTBF was not greatly varied from its baseline value (value of 1.2 BL, 1.4 BL and 1.6 BL were used). However, it was varied enough to cause decreases in equipment failure. The fact that corrective maintenance hours did not correspondingly increase indicates a potential problem in the model.
2. Planned maintenance hours.  
The implications of this variable are inconclusive. There is no clear cut reason why changes in MTBF would be expected to have any effect on planned maintenance hours.
3. Maintenance personnel queue hours.  
Increases in equipment failures might be expected to cause increases in queues. But certain increases can be handled by increasing workload without a need for queues. The data from the study are not clear whether the equipment failures were large enough to be expected to result in queues.
4. Percent of time at C-1 (Aux. eng.)
5. Percent of time at C-1 (AAW search & track).  
The data from the study were not sufficient to determine if the increased equipment failures were large enough to expect a degradation in equipment readiness.
6. Troubleshooting queues- total ship.
7. Repair queues - total ship.  
The comments for variable 3 apply here.. Whether the equipment failures increased enough to cause troubleshooting and repair queues is not apparent from the data.
8. Planned maintenance cancellations.  
The relationship between decreases in MTBF and changes in PM cancellations is obscure. Such a relationship may be present but lack of knowledge concerning its form dictated an "inconclusive" judgement.
9. FM & S/A work not done.
10. FM & S/A interrupts.
11. Division training.  
All of these variables have been classed as inconclusive because of the lack of knowledge about how increases in MTBF would be expected to effect these variables.

**TABLE 8: SUMMARY OF VALIDITY JUDGEMENTS**

**INDEPENDENT VARIABLE: NO. OF STG 2&3<sup>9</sup>**

DEPENDENT VARIABLE	DATA IMPACT			Direction of Change in Dep. Var. as STG's decrease.
	Support Model	Not Support Model	Inconclusive	
Watch Hrs (1)	X			Incr
Percent of NWW (1)	X			Incr
Maint. pers.-Q Hrs (2)			X	None
Maint. pers.-No. Qs (2)			X	None
Maint. pers.-No. intrpts (2)			X	None
Equip. Avail. pct(4)		X		Variable
Tblsht & Repair Q Hrs (4)			X	None
PM-No. delays (5)	X			Incr
PM-No. cancelled (5)	X			Incr
FM & S/A- hrs left (6)	X			Incr
FM & S/A- intrpts (6)			X	None
Trng. read.-cancelled(8)			X	None
Trng. read.-delays (8)			X	None
Trng. read.-delay hrs (8)			X	None

<sup>9</sup>Study E, Chapter II

**TABLE 8: Rationale for Validity Judgements**

1. Watch hours.  
These findings seem to be consisted with what would be expected to occur on a real ship. As number of men available decreases, mean watch hours for each remaining man qualified to stand watches would be expected to increase.
2. Percent of Standard Navy Workweek.  
When amount of work required to be done is constant, it is reasonable that decrease in total men available to do the work would result in a higher workload for the remaining men.
3. Maintenance personnel queues.
4. Maintenance personnel queue hours.
5. Maintenance personnel interrupts  
The values for these dependents variables were zero for all values of size of target group and workload level. The implications of this lack of response on model validity are not clear. It may be that equipment failures were infrequent enough that 2 men could handle the corrective maintenance load without queues or interrupts occurring. But no data is available to verify this.
6. Mean Equipment Availability Percent.  
The results obtained from the simulation indicated that when the size of the target group decreased, equipment availability increased until target group dropped to 2; availability percent then dropped to its lowest point. This finding does not support model validity.
7. Troubleshooting and Repair Queues.  
No significant effect on this dependent variable was obtained. This finding was judged as inconclusive. At first glance it might appear that decrease in personnel available for maintenance would certainly increase the number of troubleshooting and repair queues on equipment maintained by the reduced number of personnel. However, with all personnel present, the highest number of queues was 0.022. This value is so low that perhaps it should not be expected to decrease as maintenance personnel decreases.
8. Planned Maintenance Delays.
9. Planned Maintenance Cancellations.  
Both of these variables increased as group size decreased. Decrease in maintenance men from 6 to 2 would be expected to have this effect on planned maintenance tasks.



10. FM and S/A hours undone.  
As number of personnel available to do the work decreased, the hours of work not done increased. This finding is consistent with expectations.
11. FM and S/A interrupts.  
This variable was not affected by decreases in personnel available. This finding was categorized as inconclusive because it was not clear what effect would be found on-board ship. FM and S/A interrupts occur when a higher priority work requirement exists. Whether or not decreases in personnel should have increased higher priority work requirements and therefore increased interrupts were not clear.
12. Mean Cancellations (Training Readiness).
13. Mean Delays (Training Readiness).
14. Mean Delay Hours (Training Readiness).

The study data showed that these variables were not effected by changes in group size. Delays and cancellations in training readiness exercises, occur when required equipment is not operating. Whether decreases in STG's from 6 to 2 would actually cause large enough equipment down time to cancel delay and exercises on a real ship was not clear.

TABLE 9: SUMMARY OF VALIDITY JUDGEMENTS

INDEPENDENT VARIABLE: LEVEL OF FM & S/A WORKLOAD<sup>10</sup>

DEPENDENT VARIABLE	DATA IMPACT			Direction of Change in Dep. Var. as Work- load decreases
	Support Model	Not Sup- port Model	Incon- clusive	
Watch hrs (1)	X			None
Percent of NWW (1)	X			None
Maint. pers.- No. Qs (2)	X			None
Maint. pers.- Q hrs (2)	X			None
Maint. pers.- No. intrpts (2)	X			None
Equip. avail. pct. (4)		X		Decr
Tblsht. & repair Q hrs (4)	X			None
PM- No. delays(5)	X			None
PM- No. cancelled (5)	X			None
FM & S/A- hrs left (6)	X			Decr
FM & S/A- intrpts (6)	X			None
Trng. read.- cancelled (8)	X			None
Trng. read.- delays (8)	X			None
Trng. read.- delays hrs(8)	X			None

<sup>10</sup>Study F. Chapter II

**TABLE 9: RATIONALE FOR VALIDITY JUDGEMENTS**

1. Watch Hours.  
Since watch station manning takes priority over all other tasks, except evolution, a decrease in FM & S/A workload from 100% of normal to 20% of normal would be expected to have no effect on the total number of watch hours worked.
2. Percent of Standard Navy Workweek.  
The finding that % SNWW decreases as workload imposed on the men decreases is entirely consistent with what would be expected to occur on board a ship.
3. Maintenance personnel queues
4. Maintenance personnel queue hours
5. Maintenance personnel interrupts  
The relationship between FM & S/A workload and maintenance personnel performance is remote and therefore variation in the workload would be expected to have little or no influence on these 3 dependent variables.
6. Mean Equipment Availability Percent.  
Equipment availability percent decreased as workload decreased. This finding is inconsistent with the expectation; certainly decrease in FM workload would not result in decreases in equipment readiness aboard a ship.
7. Number of troubleshooting and repair queues.  
FM & S/A workload would be expected to have no effect on this dependent variable. This finding is consistent with reality.
8. Planned maintenance delays.
9. Planned maintenance cancellations.  
Both of these variables are only remotely related to FM & S/A workload. The finding that decreases in workload had no effect on these variables is reasonable.
10. FM & S/A hours undone.  
It is obvious that as external FM & S/A workload decreases the hours of such work not accomplished should also decrease.
11. FM & S/A interrupts.  
The finding that decreases in FM & S/A workload resulted in decreases in FM & S/A interrupts is obviously reasonable. If interrupts are zero at 100% workload, then reductions in workload can result in no further decreases in interrupts.
12. Cancellations (Training Readiness).
13. Delays (Training Readiness).
14. Delay hours (Training Readiness).  
These 3 variables have been classed as supporting the model because it would be expected that decreases in FM & S/A workload would have no effect on training readiness.

**TABLE 10: SUMMARY OF VALIDITY JUDGEMENTS**

**INDEPENDENT VARIABLE: TASK REDUCTION & MANPOWER REDUCTION**

DEPENDENT VARIABLE	DATA IMPACT			Direction of Change in Dep. Var. as Work-Load decreases
	Support Model	Not Support Model	Inconclusive	
Total Workload (1)	X			Decr
Percent of NWW (1)	X			Decr
				Direction of Change in Dep. Var. as Man-ning decreases
Total Workload (1)	X			Incr
Percent of NWW (1)	X			Incr

**TABLE 10: RATIONALE FOR VALIDITY JUDGEMENTS**

1. Mean hours worked.
2. Percent of SNWW.  
Both of these variables decreased when the 64 hours of ships work was removed from the ship. This finding clearly supports Ship II validity.
3. Mean hours worked.
4. Percent of SNWW  
After eight men were removed, these dependent variables increased in value, a result which would be expected to occur aboard a ship.

developers and on a non-overlapping set of problems. Little data on consistency is therefore available from examination of Ship II studies. However, very little of Ship II input data is based on subjective estimates of the users. Therefore, the results obtained with Ship II would be expected to show adequate consistency across users but no data exist to show that this is the case. The data on reliability of Ship II outputs was reported by Schwartz, Parker & Phodes (1970). The data from this study will be presented without comment because it is difficult to determine the implications of this data for model quality. However, this study does show that data aggregated at the total ship level is more reliable and fewer number of replications will be necessary to achieve any given level of precision than if division level data is used.

The method used for calculation of reliability values is as follows:

a. All output variables studies were listed (Column 1, Table 11).

b. Measurement units and levels of treatment were assigned (Column 2, table 11).

c. The pooled mean value of the statistic was computed for all relevant model runs (Column 3). The pooled mean value,  $\bar{x}$ , is equal to the sum of the means divided by the number of runs, i.e.,  $\bar{x} = \sum x_i / N$ .

d. The pooled standard deviation of the statistic was then computed (Column 4), in the following fashion:

$$s = \sqrt{\sum s_i^2 / N} ;$$

where s is the pooled standard deviation,

$s_i^2$  is the sample variance, and

N is the number of samples

e. Since the primary concern was the probability that results would be repeated within 10 and 20 percent of the expected value ( $\bar{x}$ ), confidence bandwidth of  $\pm .10$  and  $\pm .20$  were selected in this reliability evaluation (Columns 5 and 6). For each output variable treated in the test runs, the mean and standard deviations were used to compute the probability

that the measured output would fall within the confidence bandwidth. The method of computation was:

$$\text{where } R[c] = \phi(u) - \phi(-u),$$

$$u = \frac{c\bar{x}}{s},$$

$R[c]$  = Reliability value

$\phi$  = Fractile of the normal distribution

$\bar{x}$  = Pooled mean

$s$  = Pooled standard deviation

$c$  = Relative confidence bandwidth

This computation first determines the number of standard deviations which fall between  $\pm 10\%$  (or  $\pm 20\%$ ) of the calculated mean. The percentage of the normal curve which falls within this number of standard deviations from the mean is then determined. This percentage figure is the reliability indicator which appears in the tables.

TABLE 11

## RELIABILITY COMPUTATION FOR SHIP II MODEL OUTPUTS

VARIABLE	LEVEL	$\bar{x}$ *	s	RELIABILITY INDICATOR	
				+ 10%	+ 20%
Mean CM Hrs/Wk	Hrs Total Ship	320.13	49.68	48	80
Mean CM Hrs/Wk for Watchstanders (WS)	N Div	0.0015	2.828	**	**
"	OC "	0.3255	0.146	**	**
"	OE "	6.757	0.495	82	93
"	A "	0.2045	0.02	71	96
"	1st "	0.0585	0.01	45	77
"	B "	2.3595	0.053	98	99
"	R "	0.919	0.327	*	**
Mean CM Hrs/Wk Total Ship	Avg. WS	0.8155	0.032	99	99
Mean CM Hrs/Wk for Nonwatchstanders (NWS)	N Div	0.0285	0.01	**	45
"	OC "	0.2065	0.069	**	45
"	OE "	10.132	0.692	86	99
"	2nd "	0.5015	0.247	**	**
"	F "	1.307	0.406	**	47
"	A "	0.2365	0.123	**	**
"	1st "	0.095	0.062	**	**
"	B "	1.1005	0.514	**	**
"	R "	1.9215	0.356	**	71
Mean CM Hrs/Wk Total Ship	Avg. NWS	0.7385	0.049	86	99
Mean PM Hrs/Wk	Hrs Total Ship	539.13	8.677	99	99
Mean PM Hrs/Wk for WS	N Div	0.28	0	99	99
"	OC "	1.406	0.01	99	99
"	OE "	1.713	0.071	98	99
"	OI "	0.4885	0.02	98	99
"	A "	1.5675	0	99	99
"	1st "	0.342	0	99	99
"	M "	1.8765	0	99	99
"	B "	2.459	0.022	99	99
"	R "	3.095	0.146	96	99

\* Some entries were omitted due to zero values which would be meaningless in terms of this analysis.

\*\* Reliability is very small

TABLE 11 (CONT.)  
RELIABILITY COMPUTATION FOR SHIP II MODEL OUTPUTS

VARIABLE	LEVEL	$\bar{x}^*$	s	RELIABILITY INDICATOR $\pm 10\%$	RELIABILITY INDICATOR $\pm 20\%$
Mean PM Hrs/Wk Total Ship	Avg. WS	1.5265	0	99	99
Mean PM Hrs/Wk for NWS	OC Div	0.741	0.022	99	99
"	OE "	1.986	0.022	99	99
"	OI "	1.5015	0	99	99
"	2nd "	2.3595	0.014	99	99
"	F "	2.212	0.024	99	99
"	A "	6.677	0.196	99	99
"	1st "	0.166	0	99	99
"	M "	2.1995	0.035	99	99
"	B "	3.582	0.024	99	99
"	R "	7.061	0.309	98	99
Mean PM Hrs/Wk Total Ship	Avg. MWS	1.7275	0	99	99
% Navy Work Week (NWW) for WS	N Div	94.0	0	99	99
"	OC "	92.5	0.5	99	99
"	OE "	116.0	2.0	99	99
"	OI "	87.0	1.0	99	99
"	A "	92.0	0	99	99
"	1st "	107.0	0	99	99
"	M "	97.5	0.5	99	99
"	B "	98.5	0.5	99	99
"	R "	94.5	0.5	99	99
"	Avg. WS	97.0	0	99	99
% NWW for NWS	N Div	58.0	1.0	99	99
"	OC "	72.5	0.5	99	99
"	OE "	66.5	0.5	99	99
"	OI "	30.0	0	99	99
"	2nd "	43.5	0.5	99	99
"	F "	32.5	0.5	99	99
"	A "	58.5	2.5	98	99
"	1st "	47.5	0.5	99	99
"	M "	47.5	0.5	99	99



TABLE 11 (CONT.)

## RELIABILITY COMPUTATION FOR SHIP II MODEL OUTPUTS

VARIABLE	LEVEL	$\bar{x}$	s	RELIABILITY INDICATOR	
				$\pm 10\%$	$\pm 20\%$
% NW for NWS (cont.)	B Div.	78.0	0	99	99
"	R "	67.5	1.5	99	99
"	S "	69.5	0.5	99	99
"	Avg. NWS	54.5	0.5	99	99
Mean # Mandays/Wk FM & S/A Left	Total Ship	31.53	3.179	67	95
Undone	N Div.	6.238	0.449	82	99
"	OC "	0.5075	0.098	**	71
"	OE "	2.594	0.711	**	54
"	2nd "	0.326	0.057	**	73
"	F "	0.1645	0.035	**	58
"	A "	0.5685	0.440	**	**
"	1st "	2.708	0.766	**	**
"	M "	0.727	0.017	99	99
"	B "	4.349	0.633	52	85
"	R "	2.61	0.801	**	48
"	S "	9.859	0.735	81	99
Mean # FM & S/A Jobs Interrupted/Wk	Total Ship	382.99	10.22	99	99
"	N Div.	33.55	0.650	99	99
"	OC "	18.6	0.3	99	99
"	OE "	15.8	0.1	99	99
"	OI "	22.65	0.35	99	99
"	2nd "	15.1	0.1	99	99
"	F "	20.95	0.15	99	99
"	A "	8.85	0.15	99	99
"	1st "	58.0	2.0	99	99
"	M "	36.9	1.1	99	99
"	B "	32.25	0.75	99	99
"	R "	60.0	1.0	99	99
"	S "	37.5	0.5	99	99

TABLE 11 (CONT.)

## RELIABILITY COMPUTATION FOR SHIP II MODEL OUTPUTS

VARIABLE	LEVEL	$\bar{x}^*$	S	RELIABILITY INDICATOR	
				$\pm 10\%$	$\pm 20\%$
Div Training (#Sched/ # Perform)	Total Ship	0.9167	0.023	99	99
"	N Div	0.7184	0.024	99	99
"	OC "	0.5921	0.01	99	99
"	OE "	0.7871	0.076	67	95
"	OI "	0.7495	0.01	99	99
"	2nd "	0.8402	0	99	99
"	F "	0.8861	0.01	99	99
"	A "	0.5789	0.032	94	99
"	1st "	0.7981	0.01	99	99
"	M "	0.9167	0.023	99	99
"	B "	0.8986	0.014	99	99
"	R "	0.8918	0.01	99	99
"	S "	0.76	0	99	99
Ship Training Readiness Ratio	Total Ship	0.1949	0.065	**	**
Mean # PM Cancelled/ Wk	Total Ship	52.92	2.884	93	99
"	Daily	25.71	2.318	74	97
"	Weekly	21.79	0.817	99	99
"	Monthly	7.10	0.8	63	92
"	Quarterly	1.40	0.2	52	84
Mean Q Hrs for Troubleshoot	Total Ship	5.635	2.536	**	**
Mean Q Hrs for Repair	Total Ship	29.7	19.457	**	**
Q Hrs/Wk	Total Ship	11.261	1.688	48	82
"	BT	0.241	0.241	**	**
"	EM	0.2645	0.066	**	54
"	EN	0.1855	0.185	**	**
"	ET	2.6405	0.098	98	99
"	ETN	4.883	2.293	**	**
"	ETR	0.797	0.596	**	**

TABLE 11 (CONT.)

## RELIABILITY COMPUTATION FOR SHIP II MODEL OUTPUTS

VARIABLE	LEVEL	$\bar{x}^*$	s	RELIABILITY INDICATOR	
				$\pm 10\%$	$\pm 20\%$
Q Hrs/Wk (Cont)	ET, ETN, ETR	14.171	8.426	91	99
"	FTM	0.125	0.024	48	81
"	GMG	0.0765	0.077	**	**
"	IC	0.8085	0.233	**	52
"	MM	0.5498	0.348	**	**
"	RM	0.241	0.017	**	99
"	SFM	0.25	0.25	**	**
"	ST	0.142	0.02	52	84
Time at C-1 Status	Total Ship	0.8305	0.103	59	90
"	Aux Eng A	49.186	74.927	**	**
"	Steam & Trbn	48.362	26.082	**	**
"	Ship Control	96.424	3.574	99	99
"	Deck & Damage	14.042	0.081	99	99
"	Lube Oil Sys	85.901	6.864	79	99
"	AAW Srch & Track	17.271	17.386	**	**
"	Tacan	40.66	27.209	**	**
"	AAW/Wpns Cont.	5.41	4.68	**	**
"	AAW/Miscell	15.85	4.984	**	48
"	AAW-ASW/Rdr	69.008	30.259	**	**
"	Dist				
"	ASW/Srch & Track	70.243	9.849	52	84
"	ASW Fire Cont.	83.158	16.75	**	67
"	GNL/Electric & Test	95.876	3.623	99	99
"	SUW/Srch & Track	65.303	33.482	**	**
"	SUW/Gun Sys	23.745	11.715	**	**
"	CAC/Ext Comm	50.946	9.061	**	74
"	CAC/Int Comm	56.019	42.329	**	**
"	CAC/Navigation	17.836	2.116	70	92
"	Boilers	10.593	7.311	**	**
"	Boiler Control	39.923	38.766	**	**

## D. Sensitivity

### 1. Discussion of Concept

Sensitivity can be defined as the degree to which the dependent variables in a model are responsive to changes in values of independent variables.

If a model is to be useful for investigating relationships between variables, the dependent variables must respond properly to changes in the values of the independent variables. One of the major problems in testing sensitivity is determination of what this proper response is. Testing of model sensitivity therefore requires data on real world relationships among variables. To illustrate this point, consider two types of real world relationships among independent and dependent variables: (1) the real world relationship between variables is high positive or negative; (2) the real world relationship is small or zero. Assume that a sensitivity test has been made and it has been found that an output variable does not change as an input variable is changed. If the first relationship holds, then the model shows lack of sensitivity. On the other hand, if relationship 2 holds, then the model is validly representing the real world situation. Without knowing which relationship underlies the input-output variables, either situation may be equally likely. The results of a sensitivity test can be properly interpreted only when data on actual relationships among the variables is available. Simulation models are usually used where problem complexity precludes either analysis or empirical study of the problem. The type of empirical data needed to properly interpret a sensitivity analysis may be difficult to obtain simply because of the nature of the situations to which simulation models are applied.

As defined in this paper, sensitivity represents the degree of statistical relationship between input and output values. This degree of relationship is indicated by the proportion of output variance accounted for by variation in input values. When the variance of an output variable is small, it may seem appropriate to conclude that the output is not sensitive to whatever input variable was varied. However, it is entirely possible for a strong degree of relationship between input and output variables to exist when output variance is small. The output variable would indeed be sensitive to variation in the input variable even though output variance is small.

One of the problems with this definition of sensitivity is choosing the appropriate measure of sensitivity. The appropriate index of proportion of variance in output accounted for by input variation is  $\omega^2$  (Hayes, 1963). However, this statistic was not calculated in the studies reviewed in Section II. Nevertheless, the presence or absence of a statistical relationship can be roughly determined if the data were subjected to tests of significant of differences between independent variable values. The occurrence of a significant value for such a test of significance guarantees that some degree of statistical relationship is present in the data. However, it is not possible to estimate the strength of this relationship from the results of the test.

The problem in using statistical significance as the criteria for sensitivity is that strong degrees of statistical relationship may be missed by this criteria. It is true that a significant result guarantees that some (possibly small) degree of relationship exists but it is also entirely possible for a strong degree of statistical relationship to exist in data which do not exhibit a significant result. The factor which determines whether a significant statistical test really represents a strong statistical relationship is sample size. As Hayes (1963) says: "Virtually any study can be made to show significant results if one uses enough subjects, regardless of how nonsensical the result may be" (P. 326). The sample sizes used in all of the Ship II studies have been small (10 at largest); therefore there is reason to feel that all the significant results represent at least a moderate degree of statistical association. But because of the low sample size, it is not unlikely that strong statistical relationships might have been present when a test was non-significant. Unfortunately, the studies do not contain the data needed to clarify the situation. Nevertheless, the sensitivity information which does exist will be summarized even though it may be incomplete and difficult to interpret.

## 2. Evaluation of Ship II Sensitivity

A summary of information about Ship II sensitivity, based on all past studies of Ship II, is contained in this section. The indicator of the presence of a statistical relationship is a significant statistical test. With one exception, therefore, these tables will class as sensitive only those dependent variables which show a statistically significant relationship with the independent variable. The one exception is those variables for which a "no change" relationship was judged in the validity tables as lending support

to model validity. In these cases, lack of significant relationship between input and output cannot be classed as insensitivity because such a relationship reflects the kind of variation found in the real world. Judgements of this type are classed in the "non-applicable" column in Tables 12 - 18. Each table summarizes data for a separate independent variable. The dependent variables in the tables are the same as in the validity tables (tables 4 - 10). As noted in those tables, the number in parenthesis after each dependent variable in tables 12 - 18 refers to the paragraph in section B of Appendix B where definition of that variable will be found.

An examination of the seven sensitivity tables shows a mixed result. In three studies, the majority of the dependent variables were found to be sensitive to the independent variable variation (Tables 12, 13 & 18). In one study the results were about evenly divided between sensitive and non-sensitive (Table 16). None of the dependent variables in the remaining study were sensitive to either of two independent variables (Tables 14 and 15). The question of interest is whether the lack of sensitivity shown in some of these studies is a characteristic of the model or a result of the studies. With regard to the results in Tables 14 and 15, the authors of that study (Study B, Chapter II) believe that the effect of MTBF and TIF variation were masked by large equipment downtimes which occurred because of long parts deferrals. For some equipments readiness was degraded to the point that some scheduled scenario events could not take place. It is reasonable that with large amounts of equipment downtimes occurring, variation in MTBF and TIF would not be significant. This possible masking effect appears even more reasonable when considering that the range over which MTBF and TIF varied was small. MTBF varied only between baseline value and 1.6 BL; TIF varied between BL and 0.625 BL.

One other factor should be kept in mind when examining Tables 14, 15, 16 & 17. The first part of this section pointed out that sample size determined the correspondence between statistical significance and degree of statistical relationship. With very large samples, a weak degree of relationship could be present even though the statistical test is significant. Conversely, with very small samples, a strong degree of relationship could be present even when a test is non-significant. The sample size for these two studies were small enough that a real possibility exists that the latter case applies. For example, Tables 16 and 17 were

**TABLE 12: SUMMARY OF SENSITIVITY JUDGEMENTS**

**INDEPENDENT VARIABLE: REDUCED MANNING-TOTAL SHIP<sup>14</sup>**

DEPENDENT VARIABLE	DATA IMPACT		Non-Applicable
	Sensitive	Not Sensitive	
Percent of NWW (1)			
Watchstanders	X		
Non-Watchstander	X		
Planned Maint. hrs (1)			
Watchstanders	X		
Non-Watchstanders	X		
Corr. maint. hrs (1)			
Watchstanders	X		
Non-Watchstanders		X	
Maint. pers.-			
Q hrs (2)	X		
PM-No. cancelled (5)	X		
FM & S/A-hrs left (6)	X		
FM & S/A- intrpts (6)	X		
Div. trng.- hrs/wk (7)	X		
Pcnt time at C-1 (tot ship) (9)		X	
Tblsht Q hrs (4)	X		
Repair Q hrs (4)		X	
Trng. read.-hrs perf/hrs sched (8)		X	

<sup>14</sup> Study A, Chapter II

**TABLE 13: SUMMARY OF SENSITIVITY JUDGEMENTS**

**INDEPENDENT VARIABLE: SCENARIO LOAD<sup>15</sup>**

DEPENDENT VARIABLE	DATA IMPACT		Non-Applicable
	Sensitive	Not Sensitive	
Percent of NWW (1)			
Watchstander	X		
Non-Watchstander	X		
Total Workload			
Total division	X		
Watchstanders	X		
Non-Watchstanders	X		
Watch Hrs (1)			
Total division	X		
Watchstanders	X		
Non-Watchstanders	X		
Div. Trng. Hrs (1)			
Total division	X		
Watchstanders	X		
Non-Watchstanders	X		
Evolution Hrs (1)			
Total division	X		
Watchstander	X		
Non-Watchstander	X		
Planned Maint. Hrs (1)			
Total division	X		
Watchstander		X	
Non-Watchstander	X		
Corr. Maint. Hrs (1)			
Total division	X		
Watchstander		X	
Non-Watchstander	X		

<sup>15</sup>Study C, Chapter II



**TABLE 13: CONTINUED SUMMARY OF SENSITIVITY JUDGEMENTS**

**INDEPENDENT VARIABLE: SCENARIO LOAD**

DEPENDENT VARIABLE	DATA IMPACT		Non-Applicable
	Sensitive	Not Sensitive	
Fac. Maint. Hrs (1)			
Total division		X	
Watchstander	X		
Non-Watchstander	X		
Supp/Admin Hrs (1)			
Total division	X		
Watchstanders	X		
Non-Watchstander	X		
PM- No. Sched (5)		X	
PM- Total manhours (5)		X	
FM & S/A Hours left (6)	X		
FM & S/A Intrpts (6)	X		
Div. Trng.- No sessions(7)	X		
Div. Trng.- Attendance (7)	X		
Div. Trng.- Duration (7)	X		

**TABLE 14: SUMMARY OF SENSITIVITY JUDGEMENTS**

**INDEPENDENT VARIABLE: TIME IN FUNCTION**<sup>16</sup>

DEPENDENT VARIABLE	DATA IMPACT		Non-Applicable
	Sensitive	Not Sensitive	
Corr. maint. hrs(1)		X	X
Planned Maint. hrs (1)		X	
Maint. pers-Q hrs (2)		X	
Pcnt time at C-1 (Aux. eng.) (9)		X	
Pcnt time at C-1 (AAW sch & trk) (9)		X	
Tblsht Q hrs (4)		X	
Repair Q hrs (4)		X	
PM- No. cancelled (5)		X	
FM & S/A- hrs left (6)		X	
FM & S/A intrpts (6)		X	
Div. Trng.- hrs perf/hrs sched(7)		X	
Trng. read.- hrs perf/hrs sched(8)		X	

<sup>16</sup>Study B, Chapter II

TABLE 15: SUMMARY OF SENSITIVITY JUDGEMENTS

INDEPENDENT VARIABLE: TIME BETWEEN EQUIPMENT FAILURE<sup>7</sup>

DEPENDENT VARIABLE	DATA IMPACT		Non-Applicable
	Sensitive	Not Sensitive	
Corr. maint. hrs (1)		X	
Planned maint. hrs (1)		X	
Maint. pers-Q hrs (2)		X	
Pcnt time at C-1 Aux. eng. (9)		X	
Pcnt time at C-1 (AAW sch & trk) (9)		X	
Tblsht Q hrs (4)		X	
Repair Q hrs (4)		X	
PM- No, cancelled(5)		X	
FM & S/A- hrs left (6)		X	
FM & S/A- hrs left (6)		X	
Div, trng.- hrs perf/hrs sched(7)		X	
Trng. read.- hrs perf/hrs sched(7)		X.	

<sup>17</sup>Study B, Chapter II

**TABLE 16: SUMMARY OF SENSITIVITY JUDGEMENTS**

**INDEPENDENT VARIABLE: NO. OF STG 2&3<sup>18</sup>**

DEPENDENT VARIABLE	DATA IMPACT		Applicable
	Sensitive	Not Sensitive	
Watch Hrs. (1)	X		
Percent of NWW (1)	X		
Maint. pers.-Q Hrs (2)		X	
Maint. pers.- No. Qs (2)		X	
Maint. pers.- No. intrpts (2)		X	
Equip. Avail. pct(4) Tblsht & Repair Q Hrs (4)	X	X	
PM-No. delays (5)	X		
PM-No. cancelled (5)	X		
FM & S/A- hrs left (6)	X		
FM & S/A intrpts (6)		X	
Trng. read.- cancelled (8)		X	
Trng. read.- delays (8)		X	
Trng. read.- delay hrs (8)		X	

<sup>18</sup>Study E, Chapter II

**TABLE 17: SUMMARY OF SENSITIVITY JUDGEMENTS**  
**INDEPENDENT VARIABLE: LEVEL OF FM & S/A WORKLOAD<sup>19</sup>**

DEPENDENT VARIABLE	DATA IMPACT		Non-Applicable
	Sensitive	Not Sensitive	
Watch hrs (1)			X
Percent of NWW (1)	X		
Maint. pers.- No. Qs (2)			X
Maint. pers.- Q hrs (2)			X
Maint. pers.- No. intrpts (2)			X
Equip. avail. pct. (4)	X		
Tblsht. & repair Q hrs (4)			X
PM- No. delays(5)			X
PM- No. cancelled (5)			X
FM & S/A- hrs left (6)	X		X
FM & S/A- intrpts (6)			
Trng. read.- cancelled (8)			X
Trng. read.- delays (8)			X
Trng. read.- delays hrs(8)			X

<sup>19</sup>Study E, Chapter II

**TABLE 18**

### SUMMARY OF SENSITIVITY JUDGEMENTS

INDEPENDENT VARIABLES: TASK REDUCTION AND MANPOWER REDUCTION<sup>20</sup>

	DATA IMPACT		
DEPENDENT VARIABLE	SENSITIVE	NOT SENSITIVE	NON-APPLICABLE
Total workload(1)	X		
Percent of NWW (1)	X		
Total workload(1)	X		
Percent of NWW(1)	X		

<sup>20</sup>Study F, Chapter II

based on a sample size of 5 and Tables 14 and 15 a size of 10. It is possible that the results in Tables 14, 15, 16 & 17 do not entirely reflect the real sensitivity of Ship II.

The input-output combinations represented in these seven tables comprise only a small number of the total number of possible Ship II input-output combinations. The conclusion which were drawn about Ship II sensitivity from the above studies should not be generalized to conclusions about the sensitivity of the entire model.

#### E. Utility

The basic question involved in evaluating model utility is how useful is the model in aiding in the solution of real problems for real decision makers. Model utility must be defined by specification of the problem areas to which the model may potentially be applied. This section will contain a discussion of the problem areas to which Ship II can be applied.

Once a user has determined the models which are generally applicable to his problem, the selection of models which are specifically appropriate depends mainly on examination of model outputs and inputs. A research problem is defined by its important independent variables. A potential user must therefore examine Ship II independent (input) variables to determine if Ship II can be applied to his particular problem. A user must also examine the model output data to insure that the model can produce the data he needs to evaluate his tentative problem solutions. It is possible for a model to have the required input variables to study a problem of interest but not have the output variables which the user requires to assess the effect of his independent variables.

A distinction between two different types of applications of a model is useful in discussing Ship II utility. These two types of applications will be arbitrarily called type A and type B applications. A type A application will be used to refer to problems whose independent variables correspond directly with the input variables of the model. In this case, problem formulation is simple: the user selects from the set of model input variables that subset which is identical to the independent variables of his problem.

A model can still be applied even if the problem independent variables do not directly correspond to a subset of the model input variables, but an additional step is necessary:

the user must determine the effect of changes in his independent variables on the model input variables. When this effect is known, the further steps of using the model are the same as in a type A application. This type of application is defined as a type B application. No straightforward method exists for determining whether a given problem can be studied using a particular model by a type B application. The process depends mainly on the skill of the users.

Determination of model validity for type B applications is complex. The validity of the model outputs for the users independent variables (which are different from the model input variables in a type B application), will depend upon how accurately the user specifies the relationship between his independent variables and the model input variables. The quality of results from type B applications may depend as much on the specification of this relationship as it does on the quality of the model itself.

#### 1. Ship II Classes of Applications

The Ship II input data (independent variables for studies using Ship II) can be grouped into four classes:

- Manning information. These data include descriptions of billets, lists of assigned rates, ratings, and NECs, etc.
- Equipment information. Data in this class consists of such items as failure rates, equipment identification codes, use factors, and maintenance times, etc.
- Task and training information. These data include such items as task identification codes, task performance times, and skill type and level required to perform the task.
- Operations requirements information. These data include lists of required exercises and evolutions, frequency and performance times, as well as ship readiness condition (general quarters, etc.)

These four types of data define the four general classes of studies which Ship II can be used for. Each of these four will be discussed in more detail, but no attempt will be made to define all types of studies to which Ship II can be applied.



#### a. Manning Set Studies

The model allows for changes to be made in the ship-board manning set six. The procedure for changing manning set is not overly complicated. In addition to removing and/or adding input data cards corresponding to the personnel to be removed and/or added, several other model areas may need changes. For example, a new manning set may require changes in watch assignments, overall amount of work assigned, work responsibilities, maintenance crew structure, etc., depending upon the types and degree of personnel restructuring.

The most obvious type of study based upon change in manning set is to study the effects of changing the gross numbers of personnel on the ship, or within certain divisions, or within different rating groups. In conjunction with the changes in numbers of men on board, the personnel skill levels can be similarly manipulated to assess the results of those changes in terms of ship operating (output) characteristics. Different mixes of numbers of men and skills types can be evaluated to try to achieve a specific output result (e.g., specified work week levels), to arrive at an optimum manning set, or to investigate degradations resulting from different manning mixes.

Various combinations of rate/rating/NEC can be used to study changes in skill levels to investigate a majority of skill oriented questions of interest to Navy planners, such as readiness, performance of maintenance, training, workload statistics, errors, delays, etc. An example application might concern the effect of on-the-job training (OJT) on the workload of a particular ship's division. The OJT condition could be demonstrated by allowing some of the lower rate/rating combinations to perform maintenance on selected equipment they were not previously eligible to work on, thus restructuring the breakdown of work within the division, to see what effects that would have on the overall achievement of the division's objectives.

#### b. Equipment Set Studies

This type of study involves making changes in the model's equipment set. Studies involving changes in the equipments on board are of a slightly more complicated nature than some of the other problem areas. Not only must changes be made in the equipment cards, but also input data related to the equipments changed must be added. Operational characteristics of the equipments to be added must be analyzed for

the equipment data categories that the model considers, e.g., deferral probabilities, MTBF, MTRR, PM, impact on readiness, and others. In addition to the above operational characteristics, the equipment must be assessed for its personnel implications and impacts, e.g., watch requirements operator/repairman levels, integration into the existing manning set, time requirements for operation, etc. In this manner the model can be used to investigate questions concerning the impact of automation, design changes, and other equipment oriented innovations upon the operation of the modeled ship, without actually having to produce the new equipments or install them on board the ship.

#### c. Operational Requirements Studies

A change in the deployment status of the ship model requires modification of many categories of input data as well as changes in the ship's operational scenario. The input data categories that must be changed are those related to the different tempos of operations associated with the different ship deployments. The ship maintenance requirements, ship operation and mission requirements, failure rates, training schedules and readiness exercises, and ships work, all depend on the deployment status of the ship. If the questions being investigated involve long periods of ship operation, it is realistic to expect the ship to undergo several changes in the tempo of operations due to changes in deployment.

#### d. Task Requirement Studies

In this type of study, the external task load imposed on the crew is varied. This load can be varied directly by changes in the workload for Facilities Maintenance, Support and Administration, and Planned Maintenance. It can be effected indirectly by changing equipment MTBF, Corrective Maintenance times, and scenario load (which effects readiness condition, number of readiness training exercises, and number of evolutions).

In the simplest study of this type, the external task load is varied to determine the effect on the workload of the crew. Often the question of interest is whether any individuals, NECs, rates, are consistently over or under worked. A natural extension of this type of study when certain personnel are under worked is removal of these personnel from the ship after assigning their remaining tasks to other individuals. The model is then run with both reduced tasks

and reduced manning to determine if the remaining personnel can perform the reduced task set (plus all other work requirements which are not reduced, such as watch station manning).

## 2. Ship II Utility

According to Siegel (1973), for a model to have utility, it must provide data which "are not possible or which are impractical to otherwise derive or which cannot be derived more economically" (p. 9).

"There are two subquestions subsumed by this need fulfillment question: (1) does the system planner need the type of information provided by Ship II, and (2) will Ship II provide unique data and accordingly allow the decision maker to reach the appropriate decision at a higher level of confidence? There are no data available to provide an answer to the first question. However, all common sense seems to indicate that the answer is an emphatic "yes". The model allows answers to a variety of questions which any personnel allocation planner would need to have answered relative to manning, manpower, and personnel subsystem considerations. Similarly, the second question also seems to be answerable in the affirmative. The Ship II studies completed to date testify to the ability of Ship II to provide data which are not available from other sources. This is particularly true because the model will be most useful for test of systems when they are in the conceptual and design definition stages of development.

One may also ask regarding the utility of any data set whether or not the information gain is worth the trouble it takes to acquire the data. This is essentially a cost/benefit question. Review of the Ship II input requirements suggests that a rather formidable task is involved in developing the input for any specific simulation. Accordingly, the benefit to the user will have to be great if the cost/benefit ratio is to assume meaningful values". (Siegel, 1972, P. 9-10)

## F. Practicality

This section will discuss Ship II from the viewpoint of the user of Ship II, who must collect the input data, run the model and interpret the output data. Regardless of how well a model satisfies all other evaluation criteria, it must satisfy certain time and cost requirements if it is going to be used. This section will discuss the major factors which affect the ease with which Ship II can be used, and the time and cost which are attendant to the use of the model.

## 1. Input Data Requirements

The list of the input data requirements is shown in Table 19. In the far left column, "C.T." is an abbreviation for card type, which is the basic designator to be used when referring to the different types of input data. A brief description of each type of input will be given in the following pages. Appendix A contains a detailed specification of every data element for each card type.

### a. Types of input data

(1) CT 20 - Rating Master List. This data comprises a list of all ratings on board the ship and upward equivalents, where they exist.

(2) CT 21 - NEC Master List. All NECs and their equivalents are listed on this card type.

(3) CT 25 - Ship Divisions. The name and number of men in each ship division are required. In addition, this CT includes scheduling information for divisional training.

(4) CT 26 - Billet List. This CT identifies each billet aboard the ship by division, rate, rating and NEC. Evolutions and personnel requirements for each are also included.

(5) CT 27 - Watch Station Manning. Each watch station aboard the ship is specified and the particular watchstanders for all stations are specified for each readiness condition for which the station is manned.

(6) CT 30 - Subsystem Data. The name and number of each subsystem on the ship and the number of equipments in each is listed on this CT. Failure detection times for each steaming condition and readiness rating information is also included for each subsystem.

(7) CT 31 - Equipment Data. Each equipment is first identified by subsystem number, equipment number and name. The operation percentage of equipment for each readiness condition is specified; this represents differential utilization of equipment during the different steaming conditions. The parameters of the distribution of equipment failures and deferrals are specified on this card type. Each equipment can be specified to be either critical or non-critical.

TABLE 19

SUMMARY OF INPUT DATA REQUIREMENTS AND SOURCES

C.T.	DATA CATEGORY	SOURCE
20	Ratings Master List	SMD
21	NEC Master List	SMD
	NEC equivalents	NEC Manual
25	Ship division and training information	SMD
26	Billet list (div., man, no., etc.)	SMD
	Augments and evolutions	Shipboard Survey
27	Watch station manning	SMD
30	Subsystem data	ROC
31	Equipment items	3M
	Watch station location	SMD or first-hand knowledge
	Operating %, MTBF	3M
	Degradation information	CASREPT
	Deferral data	3M
32	Troubleshooting data	3M
&		
33	Repair/test data	NEC manual, Quals manual, 3M data, first-hand knowledge
34	PM data	MIPS NEC manual, Quals manual, first-hand knowledge
35	Tool inventory	SMD
40	FM & S/A task data	Space
50	Training exercise reqmts	Type commander instructions, fleet data
60	Ship readiness data	3M, CASREPT
61	Subsystem Readiness Data	3M, CASREPT
90	Scenario events	Type commander instructions, fleet data

(8) CT 32 - Troubleshooting Data. On this card type, rate, rating and NEC requirements for a troubleshooting team of up to four men are specified. The parameters of the time in function distribution are also specified. If desired, the user can also specify equipment and tool requirements. The troubleshooting error probabilities are also listed (see section III-B-2).

(9) CT 33 - Repair/Test Data. The data in this card type are nearly the same as required for the troubleshooting function. The team requirements (rate, rating, and NEC) and tool and equipment requirements are specified, along with parameters of the time in function distribution and the probabilities of repair errors (see section III-B-2). This information is specified for each equipment.

(10) CT 34 - PM Data. Each individual PM job and its frequency (daily, weekly, monthly, quarterly, semi-annual and annula) are first identified. The remaining data is similar to CT 32 and 33: personnel (rates, rating and NEC), equipment and tool requirements for each PM job and the parameters of the time in function distribution, are listed.

(11) CT 35 - Tool Inventory. This CT lists each type of tool and test equipment and the number of each aboard the ship.

(12) CT 40 - Facilities Maintenance and Support and Administrative Data. Each job on this CT is named, identified as FM or S/A and assigned a division responsibility, if appropriate. The rate and rating for each job is specified, along with the degree of upward absorption to be used. Finally, the man hours/day is specified and the percent of each job which will be carried over if the job is not completed.

(13) CT 50 - Training Exercise Requirements. Each training exercise is listed, together with required readiness condition and subsystems.

(14) CT 60 - Ships Readiness Data. This card type contains the rules to determine total ship readiness from subsystem readiness of each mission related subsystem.

(15) CT 61 - Subsystem Readiness Data. The rules which relate to availability of each equipment in a subsystem to readiness rating of the subsystem are specified on this CT.

(16) CT 90 - Scenario. A sequential listing of commands which constitute the mission scenario is contained on this CT. Evolutions, training exercises, sea/port changes, etc. are specified by this CT.

b. Summary

This list of input data requirements demonstrates that collection and preparation of this input data could constitute a major problem for a Ship II user. The studies done so far have shown that about 3 man months is usually required to prepare a new set of data for a total ship application.

2. Parametric Variation Ratios

The easiest way to modify the model's input data is by varying the parametric variation ratios (PVR). The model includes 35 PVRs that can be changed to induce corresponding changes in the input data categories upon which they act. Making changes in PVRs has the advantages of being a fast and simple way to induce changes in whole categories of input data without tampering with the data and without making any changes in modeling operations. The major drawback of this approach is that differential treatment of items within a data category is not allowed; i.e., a change of PVR treats all the data in the corresponding data category the same. If an experimental design calls for some items in a data category to be changed while others are to be changed in a different way or remain unchanged, the input data set for the chosen category must be pulled out and new data entered manually to satisfy the differential treatment called for in the experimental design. The 35 PVRs provided for in the current model determine the areas of inquiry that the model can be used to study most easily, i.e., the model is currently set up to deal with research questions pertaining to the 35 PVRs already included in the model. These 35 PVRs break down into seven groupings corresponding to the input card types (CT) they modify: Division Training (CT 25); Failure Detection (CT 30); Equipment Data (CT 31); Troubleshoot - CM (CT 32); Repair/Test - CM (CT 33); Preventive Maintenance (CT 34); Facilities Maintenance and Support/Administrative (CT 40). Table 20 contains a list of input variables which can be varied by PVRs.

3. Knowledge of Computer Programs.

Ship II is a very large and complicated computer program. It is composed of 128 separate subroutines and a total of about 24,000 fortran program statements. Like all

TABLE 20

PARAMETRIC VARIATION RATIOS

Training Session Duration  
Hours /Week/Man  
Failure Detection Times Under Cond. I  
Failure Detection Times Under Cond. III  
Failure Detection Times Under Cond. IV  
Failure Detection Times Under Cond. V  
Failure Detection Probability During PM  
Operation % at Cond. I  
Operation % at Cond. III  
Operation % at Cond. IV  
Operation % at Cond. V  
Mean Time Between Failure  
Probability of Degradation  
Deferrals for Assistant: Prob.  
Deferrals for Assistant: Mean  
Deferrals for Assistant: Stan. Dev.  
Deferrals for Parts: Prob.  
Deferrals for Parts: Mean  
Deferrals for Parts: Stan. Dev.  
Time in Function: Mean  
Time in Function: Stan. Dev.  
Error Probability: P1  
Error Probability: P2  
Error Probability: P3  
Error Probability: PT  
Delay Times (DT)  
Time in Function: Mean  
Time in Function: Stan. Dev.  
Error Probability: PD  
Error Probability: P2  
Probability - PTR/PTR  
Time in Function: Mean  
Time in Function: Stan. Dev.  
Manhours/Day  
% Carryover for Ships Work



such programs, debugging is never finally completed in the sense that the model has been run with all ranges of values of all input variables and all output variable values generated under these conditions tested for correctness. As a consequence, when a study is done using some model process not previously used, or some extreme input values, the possibility exists that a model defect may be encountered. When such a defect is encountered, the complexity of the program requires that debugging be done by someone familiar with the operation of Ship II. The probability of a problem of this type occurring is low because Ship II has been run a number of times. Nevertheless, it must be considered as a factor involved in use of Ship II.

Ship II does have a large number of error messages which will be printed whenever errors in input data or program operation occur. However, many of the error messages are defined in terms of specific operation of particular sub-routines rather than in terms of errors which the user could have made. For example, error #571 is described as follows: "Came out of BUMPABLE with a 5"; Error #590 is: "Entered with a man who was not defined as idle (and reserved) or as assignable to special watch repair status." Error messages of this type convey very little information to someone who is not very familiar with Ship II. They do not make apparent whether the error is caused by some action of the user or by a program defect.

#### 4. Type of Computer

Ship II is now programmed for running on a CDC 3800 computer. The use of Ship II on another computer of a different word size may require too large a reprogramming effort for a user who wants to use the model only for a particular problem, but would be worthwhile for general use. At present, a potential user will have to have access to a CDC 3800.

#### 5. Cost of Using Ship II

The total cost of using Ship II depends mainly on the cost of preparing the input data, plus the cost of computer to exercise the model. The first component, input data costs, in some applications can be the major source of cost associated with using the model. Approximately three man months are required for someone familiar with Ship II to prepare a complete data set; a first-time user should perhaps plan on three and one-half to four months for data preparation, unless he is familiar with use of Navy data systems. See section 1 for further discussion of input data requirements.

Computer costs for Ship II depend, of course, on the length of time the program is run on the computer. The running time for 10 weeks for a total ship of the size of a destroyer is approximately 7 hours. A reasonable study for Ship II could compare, say, three different manning sets over a 50 week period. Such a study would require 105 hours running time. The hourly charge for the CDC 3800 at Naval Research Laboratory is \$100.00. At this rate, the study described above would incur a computer cost of \$10,500. A computer change of \$100.00/hour is considerably lower than the cost of using a commercial CDC 3800. If a user must obtain use of a computer by this means, the cost of using Ship II could be two to three times higher.

a. Program Size Problems

Ship II programs are written in Fortran IV and used on a CDC 3800 digital computer. That computer has a core storage of 57,000 storage locations (words). Ship II, on the other hand requires approximately 150,000 items of input data. In addition, the computer program itself is very large and requires another 24,000 computer core storage locations. Normally, each item of data would occupy a separate word in computer core storage, as would each program statement. But in Ship II, the number of data items and program statements is far too large for this procedure to be employed. Two space saving techniques were used to accommodate the massive amount of data required: bit packing, and the use of overlays. Bit packing refers to the storage of more than one data item in a single word of core storage. Overlays are a technique in which programs too large to fit in core are divided into independent parts which are called and executed as needed. The parts of the program not stored in core are stored in slow access peripheral storage, from which the programs are loaded into memory as needed.

Both bit packing and overlays increase the size of effective memory but only at a large increase in program running time. When bit packing is used, the input data items must be extracted from the computer word in which they are stored every time the data is needed. In Ship II, bit packing and unpacking is done by calling one of eight special bit packing subroutines. The process of transferring control to a subroutine, which involves transmittal of data from main program to the subroutine, is very slow compared with the length of time required to process the program statements themselves. Ship II has such a large amount of data that extensive bit packing was required to fit the computer.

Every subroutine in Ship II which uses input data also uses the bit packing subroutines. Because these subroutines are relatively slow and are used often, the time to execute the program is considerably longer than the time required just to execute the program statements themselves.

The use of overlays also increases the total running time of a program. When a subroutine which is not stored in core storage is required, part of the contents of core (probably another overlay) are transferred out of core to peripheral storage, and the overlay which contains the needed subroutine is transferred into core storage. The program then proceeds until the next overlay is needed and the process is repeated. The problem with the use of overlays is that process of transferring data to and from peripheral storage is much slower than the time required to execute individual program statements.

The net result of use of bit packing and overlays is that, while a large amount of data can be used with a relatively small computer, the running time for Ship II has been significantly increased. Experts in Ship II programming have estimated that over one-half of the total running time of Ship II is contributed by bit packing and overlays alone. In other words, if Ship II could be run on a computer with large enough core storage to eliminate bit packing and overlays (and such machines are commercially available) then the running time for the model would be reduced at least by one-half.

## 6. Output Data

### a. Ship II Output Reports

The output data for Ship II is presented in nine separate reports. Each report is discussed in detail in Appendix B; a brief description of each is presented below.

(1) The Personnel Record is a summary of weekly workload for each man in nine different job categories.

(2) Maintenance Personnel Summary (Rate/RTG) is a summary of maintenance personnel usage statistics accumulated by rate and rating of personnel.

(3) Maintenance Personnel Summary (NEC) is a summary of maintenance personnel usage statistics accumulated by NEC.

(4) The Readiness Summary contains the Combat readiness history of each equipment specified by the user to be a mission-related equipment, and for the total ship.

(5) The Equipment Summary is a report on the availability, down time, and components of down time for each item of equipment simulated.

(6) The Planned Maintenance Summary contains data on performance each planned maintenance job. A separate summary is provided for daily, weekly, monthly, quarterly, semi-annual, and annual planned maintenance tasks.

(7) The Facilities Maintenance and Support and Administrative Summary contains a summary of performance of each FM and SA job.

(8) The Divisional Training Summary contains data on divisional training activities.

(9) The Training Readiness Summary reports on the extent to which training exercise demands were met.

h. Output Data Processing

According to Siegel (1973) , "Ship II provides... a rich variety of output data...." (P. 5). A wide variety of statistics needed by manpower planners is included in its output. One of the major problems attendant to use of the outputs of Ship II is that user has no control over the outputs. Regardless of the problem area being studied or the interest of the user, the same output reports in an invariable format are always produced at the end of a run. Because the output of the model cannot be selected by the user, it was necessary to insure that the output would contain information which might be required to solve a wide variety of problems. As a result, the output is voluminous. For example, consider a study based on a destroyer with 12 divisions and about 300 people. This would produce 50 pages of computer printout everytime an output command is processed. Although the frequency of output can be selected by the user, all Ship II studies to date have printed a set of outputs every seven days of system history. Using this output frequency, a study covering three manning sets over a 50 week period would produce a total of 7500 pages of computer printout. A major investment of time could be required to process this volume of output to obtain the data in the form required by decision makers.

## G. Other Criteria

This section will briefly discuss several other criteria and their implications for Ship II model quality. The first two criteria to be discussed are taken from Meister (1971). Following these, the model evaluation questionnaire developed by Prather, (Hutchins, et.al., 1973) will be answered for Ship II.

### 1. System Development Applicability

#### a. Comprehensiveness

Ship II is a very comprehensive model within the limits that it is a Ship model. Any kind of equipment or system for which the required input data can be specified can be used with Ship II. Ship II can be used for ship types other than destroyers. Any ship which can be described by the functions shown in Figure 1 can be modeled with Ship II. These functions appear to describe almost all Navy ships except the small, special purpose ships, aircraft carriers, and perhaps submarines.

Another feature contributing to the comprehensiveness of Ship II is the wide variety of shipboard parameters which can be simulated. The user can specify any task set (PM, FM, etc.) task loading, manning set and mix, equipment sets, etc. that he wants, provided he can provide the necessary input data for these conditions. The basic limit on manning variation is the requirement that enough men must be available to stand all watches, but watch standing requirements can also be specified by the user.

#### b. Applicability

The relevance of this criteria to Ship II is marginal. The essence of this criteria is whether the model produces predictions of future system performance effectiveness or measures of present system performance? Ship II falls in the latter category: the model outputs descriptions of system performance for the period over which the model was run.

#### c. Timing

This criterion describes the stages of system during which the model can be applied. Ship II can be applied at any stage in the system design process for which the required manning, task and equipment input data is available.

This input data is usually taken from SMD's and other formal documents. However, Ship II can be used before such data is available to study tentative manning configurations and other such problems.

## 2. Model Characteristics

### a. Objectivity

Model objectivity refers to the degree of subjective judgements which are required to use the model. Ship II input data is very flexible in terms of source requirements; the data can originate in a wide variety of types of sources. However, in the Ship II applications to date, little of the input data has been based on subjective judgements. The large majority of data has been obtained from 3M tapes, CASREPT system forms, SMD's, and other Navy sources. Ship II meets the objectivity requirements for most of the types of studies it was designed; however, in some studies, subjective judgements may be required to generate the input data and run the model.

### b. Structure

This criteria refers to the extent to which model structure has been explicitly defined and described in detail. The structure of Ship II has been explicitly defined but details of the structure have not been effectively documented. This fact was made clear when a consultant for Ship II evaluation stated that it was difficult for him to obtain enough information to fully understand and evaluate Ship II. Most of this information is, however, contained in reports but is difficult to extract. Many of the basic characteristics of Ship II have been stated in terms of changes to TSSM, the earlier version of Ship II mentioned in Chapter I. Full understanding of these characteristics requires knowledge of TSSM, which must be obtained from other, difficult to obtain, documents. In summary, Ship II model structure has been explicitly defined but relevant information is difficult for someone not familiar with Ship II documentation to obtain.

## 3. Evaluation of Ship II on Prather Questionnaire

This section will list each questionnaire item and the response for Ship II. The ratings following each answer indicate the certainty of the response; "A" means: "I am positive of the answer", "B" means: "I am reasonably certain,

"C" means: "incomplete data tends to support the answer given", and "D" means: "no information is available on this question."

1. If the input required so voluminous and/or difficult to obtain as to pose a major factor to consider before using the model? Answer: yes; rating: A.

Comment: A list of input data required for Ship II is given earlier in this report. An experienced Ship II user will usually require approximately 3 man months to prepare a complete input data set for Ship II. For most of the input data categories, data values must be input at the start of a run; Ship II will not operate otherwise. However, depending on the purpose of the user, certain data values may be arbitrarily specified without degrading the output from the model.

2. Are the accuracy, validity, and reliability of the input data and its source well known? Answer: yes, rating: B.

Comment: Input data for Ship II are acquired from a variety of sources depending on the requirements of the user.

3. Does the model presently receive data from other computer models? Answer: no, rating: B.

Comment: No data are taken directly from other computer models. But other models could serve as a data source at the user's discretion.

4. Has a sound basis been laid by the model builders for any non-standard modeling techniques used or any innovative application of standard ones? Answer: not applicable, rating: A.

Comment: The simulation techniques used are straightforward and well documented.

5. Is the level of sophistication of the technique too high or too low for the needs of the application area? Answer: yes, rating: C.

Comment: For past applications, the model has been unnecessarily sophisticated, resulting in the user having to specify assumptions to simplify the application. However, it is possible to conceive of reasonable problem classes which would make use of the present level of sophistication. Therefore, although Ship II has been too sophisticated for past applications, future needs might justify the level of sophistication present in the model.



6. Is the modeling technique used appropriate to the application area? Answer: yes, rating: A.

Comment: Simulation is ideally suited to the study of problems involving many variables and many complex interactions among variables.

7. Is the model known to be deterministic or, if it is stochastic, is it known to be reliable? Answer: no, rating: C.

Comment: A discussion of the reliability of Ship II and a summarization of reliability data is contained in Section III-C.

8. Do the modeled system elements (e.g., blocks in the flow diagram) reflect what actually exists in the Navy? Answer: yes, rating: B.

9. Do the modeled system processes (e.g., connecting lines between blocks in the flow diagram) reflect what actually happens in the Navy? Answer: yes, rating: B.

Comment (8 & 9): Many simplifying assumptions are used in Ship II. In most cases, these assumptions are consistent with the types of simplifying assumptions usually required in modeling complex systems.

10. Is the level of detail appropriate for the application? Answer: yes, rating: C.

Comment: For many applications Ship II allows for more detail than is necessary. However, some detail can be suppressed by the user if he so desires.

11. Are all the values assigned to such parameters as work rates, fatigue factors, storage capacities, etc., correct? Answer: not applicable, rating: A.

Comment: All such data are specified and input by the user, and he may change them to study their effects (sensitivity).

12. If certain parameters are approximated, has an error analysis ever been performed to determine the cumulative error throughout the model caused by these approximations? Answer: No

Comment: See comment for item #11.



13. Is it known for what parameter and input values the model is valid and for which values (possibly extreme) it is not?  
Answer: yes, rating: C.

Comment: A discussion of Ship II validity is given in Section B. However, previous studies seem to indicate that Ship II is valid within the range of normally expected values of input variables. But these studies do not provide a complete assessment of Ship II validity.

14. Does the model presently feed data to other computer models?  
Answer: No, rating: A.

Comment: Outputs of Ship II are similar to data which would be collected by a work study team. They can be utilized in a variety of different ways depending on the user. The output data could easily be used to input to other computer models but they are not specifically designed for any particular application.

15. Is the output presented in such a way that a non-computer oriented manager can, with little or no training, use it?  
Answer: yes, rating: A.

Comment: The output data from Ship II are formulated so as to be understandable to any Navy manpower planner. Appendix B gives sample output data sheets which will demonstrate this clarity.

16. Are there readily available results from sensitivity studies showing the reaction of the models major outputs to changes in at least the major parameters within reasonable ranges of values for these parameters? Answer: No, rating: C.

Comment: Some data exists but it is incomplete. A full discussion of this topic appears in Section III-D.

17. Has the model been adequately validated by a comparison of its results with events in the actual situation it attempts to model? Answer: no, rating: B.

Comment: A full discussion of this topic appears in Section III-B.

18. Has the model ever been subjected to rigorous tests or analysis such as might be performed by a technical person uncertain about or even opposed to the model? Answer: yes, rating: C.

Comment: During the development of Ship II, Ship II was extensively reviewed by Navy personnel. Several of the personnel who participated in this review were opposed to the use of Ship II as a manpower planning aid. Reviews of the model by these personnel were critical both of model quality and of the use of computer simulation to study Navy manpower problems.

19. Were the objections or questions raised resolved in such a way as to give credibility to the model? Answer: yes, rating: C.

Comment: Some of the critical comments raised during Navy review were unjustified, being based on inaccurate knowledge of the uses of the model. Other comments did, however, reflect legitimate flaws in model construction. The response to these comments was a revision of the model. This revision has produced the latest version of the model, called Ship II. In summary, then, of the objections raised to the total ship model during Navy review, many have been resolved in a way supportive of the model. Legitimate model defects raised in this review were eliminated by revision of the model.

20. Is the model capable of and worthy of being expanded or otherwise improved so as to be of greater benefit to the Navy? Answer: yes, Rating: A.

Comment: Recent studies have indicated a large potential for improvement of Ship II which would make the model a more useful tool. Further comments on this topic are contained in Chapter V.

21. In view of the time, effort, and money expended in use of the model and the benefits actually derived in the application area, is the continued use of the model warranted? Answer: yes, rating: A.

Comment: The types of problems to which Ship II can be applied are discussed in Section E. Ship II can be used to study problems which cannot be studied in other ways or can be studied only at great expense.

After the questionnaire has been completed, the responses are used to classify the model into one of three validity classes. The term "validity" is used to mean overall model quality. Class A contains those models which have a solid technical foundation and have been thoroughly checked

TABLE 21  
QUALIFICATIONS FOR VALIDITY CLASS A

<u>QUESTION</u>	<u>ANSWER AND RATING</u>
2	YES and a or b
4	YES and a or b or not applicable
5	a or b
6	YES and a or b
7	YES and a or b
8	YES and a or b
9	YES and a or b
10	a or b
11	YES and a or b or not applicable
12	YES and a or b or not applicable
13	YES and a or b
17	YES and a or b
18	YES and a or b
	(If question 18 is answered yes and a or b, then question 19 must be answered yes a or b)
19	YES and a or b or not applicable

TABLE 22

QUALIFICATIONS FOR VALIDITY CLASS C

<u>QUESTION</u>	<u>ANSWER</u>
5	Yes and a or b and indication that sophistication is too low
6	NO and a or b
7	NO and a or b and an indication that it is known to be unreliable
8	NO and a or b and an indication of serious errors
9	NO and a or b and an indication of serious errors
10	NO and a or b and an indication that the level of detail is too low
11	NO and a or b and an indication of very serious (nearly irreparable) errors

so that the outputs are known to be accurate and reliable. Class B models are those for which sufficient information about the model is not available but major flaws have not been shown to exist. Class C models are those which are known to have major flaws which render them unsafe for operational use. Tables 21 and 22 contain the criteria for classification of a model into classes A and C. A model which does not fit either class is considered a Class B model.

The responses to the questionnaire, when scored according to these rules, show that Ship II is a Class B model.

## IV. CONCLUSIONS

### A. Validity

#### 1. Face Validity

The studies which have been done so far with Ship II have shown no major validity problems. However, these studies have looked at only a small number of the combinations of variables which can be formed with Ship II. In the seven studies which were reviewed, fifteen variables behaved in ways judged to be contrary to expectations; but no consistent pattern of non-validity is present among the dependent variables when compared across studies. The number of such relationships is small relative to those judged to lend support to model validity.

When interpreting these findings, the large number of "inconclusive" judgements should be considered. Forty eight dependent-independent variable relationships were judged inconclusive - as many as were judged valid. This large number is unsatisfactory because it means that the real impact of the Ship II studies on validity has not been assessed. But it was felt that the results of the validity survey would be more objective if only data with a relatively clear cut interpretation were used to assess model validity. As stated above, the independent-dependent variable relationships in the seven tables represent only a small number of the total such combinations which could be formed with the Ship II variables. Therefore no conclusions about Ship II as a whole can be drawn from these studies. The studies show only that certain parts of the model may be valid, some other parts may not be valid and no conclusions can be made about validity of much of the model.

#### 2. Construct Validity

The construct validity of Ship II is generally satisfactory. All but one of the shipboard functions in Ship II adequately represent the performance of these functions aboard the ship. The modeled functional performance is only an approximation to the real shipboard functional performance but such approximations are an essential feature of all simulation models. The approximations in Ship II functions are, in almost all cases, within the range which allows the functions to be feasibly modeled without distorting the output of the function to be unrepresentative of reality.

The one function which needs improved construct validity is the readiness scoring function. In Ship II, the readiness rating of the ship now depends only on equipment readiness. An unrealistically simple formula is used to calculate the subsystem and total ship readiness rating. Ship readiness on actual ships depends on other factors than equipment readiness, which are not included in Ship II.

#### B. Reliability

Two aspects of reliability were discussed. One aspect of model reliability mainly effects the cost of using a model and, conversely, precision of results obtained from a model. Little data on this aspect of Ship II is available except that for a given number of runs, data aggregated over total ship usually yields higher precision estimates than data aggregated over the division level.

Another aspect of reliability is consistency of results obtained by different users on similar problems. This aspect of Ship II was not evaluated because Ship II has been used only by its developers and personnel from NAVPERSRANDLAB. In summary, the available data are not sufficient to evaluate Ship II reliability.

#### C. Sensitivity

The data from most of the Ship II studies were generally not appropriate for evaluating sensitivity. Judgments of Ship II sensitivity were based on the results of significance tests. Most of the dependent variables studied were found to be sensitive to the independent variables used, except for the independent variables, "mean time between equipment failures (MTBF)", and "time in repair and troubleshooting functions (TIF)". None of the dependent variables used with these independent variables showed sensitivity. The lack of sensitivity to these variables may have been due to a masking variable (large deterals for parts) and to small range of variation in MTBF and TIF values. If this is found to be the case, then Ship II exhibits adequate sensitivity for most of the variables studied. However, the input-output combinations used in these studies comprise only a small number of such combinations which can be formed from Ship II; no judgments of sensitivity of combinations of variables not used in these studies can be made.

#### D. Utility

An examination of Ship II utility shows that Ship II can be applied to several problem areas of current interest to the Navy. The four general types of studies which can be done with Ship II are: (1) variation in number and characteristics of ships crew, (2) variation in amount and type of external task load imposed on the crew, and personnel requirements for the task load; (3) variation in characteristics of equipment and personnel requirements to perform CM on the equipment and, (4) variation in tempo of operations, as reflected in hours at Condition I, III or IV, number of readiness exercises, and other such variables. Studies using combinations of these four basic types can also be used. All of these studies can be performed for ships still being built, which is a major advantage of using Ship II.

Regardless of the type of study done, the following general types of output variables indicate the operation of the simulated ship: (1) the workload for each member of the crew, (2) task performance statistics which describe for each individual task of each type, how many hours were spent on the task, how often it was interrupted, etc., (3) equipment state, which describes the operational history of each equipment including a summary of corrective maintenance performance, and (4) ship readiness, including a history of readiness rating for total ship and mission related equipments and a summary of performance of readiness training exercises.

The range of problems which Ship II can study and the completeness of the output data together make Ship II a potentially useful tool of several types of current Navy problems.

#### E. Practicality

One of the major factors which has influenced the use of Ship II is that its practicality is low. Ship requires a large amount of data, part of which is difficult to obtain, is costly to run, and may require extensive output data processing. However, judgements of practicality have to be made in terms of other means available to solve the same types of problems. For most of the problems for which Ship II can be used, alternative methods may be even more costly and difficult to use than Ship II. An inexpensive, quick method for determination of the effect of changes in crew composition of a ship in terms of the type of output variables used by Ship II does not exist. The major alternative to use of Ship II would be the use of



work study teams. This method can be more costly than using Ship II for the same problem and the data obtained may be not much better.

In summary, while the practicality of Ship II is low, so is the practicality of the main alternative method for studying the same problems Ship II studies. Since solutions to these type of problems must be obtained, then Ship II should certainly be among the methods considered when study of complex manpower problems is required.

#### F. Other Criteria

##### 1. System Development Applicability

This criteria was composed of three dimensions; comprehensiveness, applicability, and timing. Ship II is very comprehensive. Many different ship classes can be studied and the user can specify an almost unlimited range of manning, workload and equipment configurations.

Relative to applicability, Ship II produces descriptions of current system performance; it cannot be used to predict future system performance. The only limitation on the timing in the system design cycle when Ship II can be applied is data availability. Ship II has been applied successfully to the DD-963, a ship which may not be in the water for another two years. The limit of application in most cases is that manning, equipment and task input data must be available.

##### 2. Model Characteristics

This criteria is composed of objectivity and model structure. Ship II satisfies the objectivity criteria in that few subjective judgements are required to use the model for most problem areas. The structure of Ship II has been explicitly defined but the information describing model structure is difficult to extract from model documents.

## V. DISCUSSION

### A. Future Use of Ship II

The evidence presented in this paper indicates Ship II has significant potential to aid in solution of many manpower planning problems for the Navy. Ship II can be applied to a variety of real problem areas of interest to the Navy and is uniquely suited for some of these problems. For the study of ships in design stage, no other techniques exist to obtain the data which Ship II can produce, (Hutchins, Prather, Barefoot & Flint, 1973). With respect to technical characteristics, the studies done to date have revealed no major flaws in the model; but these studies have not been sufficient for a complete evaluation of Ship II. Ship II is not by any means a perfect model. There probably are some validity and sensitivity problems in the model. Collection of the required input data is time consuming. The reliability of some input data sources may be low; but Ship II must be evaluated in terms of quality of outputs relative to other methods which can be applied to the same problems. Certainly Ship II produces information which is not completely valid, and which must be interpreted carefully but so does every other large computer model and so does every other non-modeling alternative to Ship II. If the manpower problems of the Navy have to be solved, which they do, then one should not discard any potentially useful methods because they are not perfect. Rather the best available methods should be used, even if the best do not have the quality one would desire. For certain types of problems, Ship II is among the best available methods accessible to the Navy. The term "best" is meant to include both quality of data and cost of obtaining the data. Ship II can be a useful tool which deserves more use than it has received in the past.

Ship II can be most effectively used to compare the relative effects of several input variable configurations. For example, comparison of several proposed changes in manning configurations or maintenance task assignments are problems which are well suited for Ship II. The model output data could be used to rank order the changes with reasonable assurance that the rank order represents reality. A user has less assurance that the absolute value of model outputs are correct. No data exist, which shows that Ship II can be used to predict the numerical values of the dependent variables because Ship II outputs have never been compared with real shipboard measurements. A user who needs to predict, for example, mean repair times for a given equipment, or total workload for certain

ratings should regard the values of these outputs produced by Ship II as rough estimates only. The same is true regarding the numerical values of all Ship II output variables. It may be of course that the numeric values of Ship II outputs will prove to be good predictors of real world data; but until this has been demonstrated, the user should treat the values only as rough estimates.

#### 1. Should Ship II be Applied During System Development?<sup>1</sup>

Personnel allocation and manning problems are increasingly under consideration during the early phases of the development of ship systems. The personnel specialist is under new pressures to make quantitative estimates of the effects of various manning and skill mixes on system effectiveness. What then can be said about the role of Ship II for system analytic purposes and about the future use of this model? The mathematically oriented sciences, including the related operations research discipline, have made significant inroads into effectiveness prediction for the hardware aspects of modern systems. However, such predictions are often found to lack predictive precision when compared against actual operational criteria of system performance. While other factors certainly affect the predictive ability of such techniques, "human factors" is one salient aspect which has not often been considered within these techniques. In this context, "human factors" refers to the effects on the operational effectiveness of the system of such factors as operator proficiency, training, manning, and the other variables and parameters of Ship II. Ship II, used in conjunction with other digital simulation models of man/machine performance, can do much to fill this gap. Digital simulation can provide a tool through which areas of personnel failure can be anticipated and, hence, the human contribution to system unreliability may be isolated. Identification of these areas, early in the equipment development cycle, will enable avoidance of crew/system mismatch and the effects of such mismatching on system reliability.

Certainly, such modeling will allow personnel planners to do what cannot be done without them. The inherent variability of humans, their viability, and their idiosyncratic tendencies make analytical or deterministic prediction of their behavior unrealistic. Though their results must be used with care, computer models, which allow for the variable and often erratic behavior of the human, seem more reasonable for the context and

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<sup>1</sup>This section is taken from Siegel (1973)

problem area which is being addressed. As has been pointed out elsewhere, we can pinpoint a target on the moon with more accuracy than we can prepare an economic forecast of the gross national product. The same may be said about human behavior in advanced systems. While manpower simulation models do not represent a panacea, they are better than nothing at all, possibly much better than might ordinarily be anticipated, and certainly superior to "engineering judgment." In the areas of personnel and man/machine modeling there is clearly no other more suitable method of attack presently available. After using such models to "test" a system, the areas receiving a negative evaluation may receive attention in a number of ways. Tasks may be reallocated over men and machines; or, the design of certain equipment items may be modified. Task completion procedures may be modified so that they will be more error free or performed more quickly. Sometimes a change in the environmental conditions, a rearrangement of the operational equipment, the provision of alerting or warning devices, the provision of job aids, modifying the level of automaticity, an increased training emphasis, or a modification in the proposed manning may be indicated. No matter what the fix may be, the effects of the change may be estimated by resimulation and estimation of whether or not the modification has sufficiently increased system effectiveness to allow the meeting of design objectives.

The use of Ship II in conjunction with other parallel models is concordant with the thinking of Apostel (1961), who pointed out that:

Modern technology utilizes a variety of models in the service of many different needs. The first requirement that a study of model building in science should satisfy is not to neglect this undeniable diversity, and to realize that the same instrument cannot perform all these functions.

Used in conjunction with other specially developed simulation models, there is available a relatively inexpensive and timely method for yielding broad insights into the nature of operator performance in a man-machine system. If the real system is large, complex, or costly, the use of these models for a predevelopment experiment may be inexpensive compared to the trial and error approach with the system itself; it will probably yield data for a larger number of cases than is practical by other approaches and at a lesser elapsed time per situation simulated.

The same reasoning applies to the situation in which the system is in being but is so heavily occupied that experimentation with changes in equipment, personnel policy or resources assignment rules may be impractical, expensive, or dangerous, or unlawful. In these cases, too, available simulation techniques are appealing.

As Shipiro and Rogers (1967) have pointed out, "...the story of man's progress in science and technology is actually the story of his success in the use of analogy and his progress in simulation." Let us grant that Ship II, like other behavioral models, is imperfect. We know the nature of its inadequacies. Accordingly, it seems that Ship II possesses a place in the personnel subsystem developmental scheme. However, if Ship II is to be employed, it would seem that such modeling should be performed in conjunction with other stochastic simulation models so that the outputs can be cross checked. In this way, the concurrent validity of Ship II will slowly become established while the tool is used for the purpose for which it was established.

#### B. Environment for Future Ship II Use

Ship II was originally intended by the Navy to be used in an operational setting. The plan was to develop a model which could be used by manpower analysts without special training in computer programming or modeling. The operation of the model would be straightforward and simple, with easily interpretable data being produced by the model. Further, the model was meant to be a general purpose model, which could be used to study many types of shipboard manning problems.

Ship II is useful for study of several types of manning problems, but the model is not appropriate for use as an operational model, mainly because of the complexity of the input data and the knowledge of the computer programs which may be required by the user. It is therefore unrealistic to expect Ship II to be used "off-the-shelf". A Ship II specialist will have to be involved in each use of Ship, either as the user, or as a consultant to the user. It is recommended, therefore, that Ship II continue to be used at NAVPERSRANDLAB. If it is desired that use of the model be eventually transferred to some other, more operationally oriented group, then a trainee from that group should be given "on-the-job" training by participating in applications of Ship II by NAVPERSRANDLAB. Even if control is eventually transferred to such a group, NAVPERSRANDLAB may have to serve as a consultant to the group because it may not be feasible to instruct someone in the details of the model function and program operation which are sometimes required.

While transfer of Ship II to an operational group would be feasible using the above transition scheme, the author believes that Ship II should not be transferred to an operational setting at all. Ship II was designed as a research tool and it should be used in an R&D environment. An operational model, by contrast, is used in a standardized, routine way, using standard inputs and outputs. Ship II is not meant to be used in this way. The model is designed to answer "what-if" questions such as what would happen if manning were changed in a certain way. This type of problem is a research problem; when used to study this type of problem, Ship II is being used as a research instrument. Therefore, Ship II can be fully effective only when used by personnel trained to perform research. The skills required of Ship II users are similar to that required by researchers in general, i.e., experimental design, statistical analysis and interpretation, evaluation of conflicting and uncertain information, and other such skills. Personnel with this type of training and background are likely to be found only in R&D environments, such as NAVPERSRANDLAB.

The statement that Ship II should be used in an R&D setting does not imply that Ship II should be applied only to hypothetical "ivory-tower" problems. Indeed, just the opposite is true: continued use of Ship II is crucially dependent on establishment of much greater communication with Navy manpower planners or project managers who are faced with problems of the type to which Ship II could be applied. Past use of Ship II has not been fully effective because such communication has not been sufficiently established. When NAVPERSRANDLAB assumed responsibility for Ship II, a series of briefings were given to personnel of various Navy organizations which deal with manning and personnel. The briefings were intended to inform these organizations that Ship II was available to assist them. The response from these briefings was apparently minimal. It appears that very few people outside of NAVPERSRANDLAB and Bureau of Naval Personnel (Pers-A3) are aware that Ship II exists. Effective future use of Ship II requires that procedures be established to bring together, in some way, the people with the manpower problems and NAVPERSRANDLAB. It is not sufficient simply to identify problems; appropriate project managers must be identified and their assistance and cooperation obtained in identifying input data sources and collecting the required data. Lack of assistance by project managers, or others who have responsibility and knowledge of ship projects, to help identify data sources and obtain the data has been a major hinderance to effective use of Ship II in past work.



C. Transfer of Ship II to Navy Personnel Research and Development Center

A transfer of NAVPERSRANDLAB functions to the Navy Personnel Research and Development Center will occur on 30 June 1973. The question of whether Ship II should also be transferred rests partly on the problem of changing the computer on which Ship II is used. Ship II is currently programmed for a CDC 3800, which has a 48 bit word. If Ship II transfers to the Center, the model would be probably be used on an IBM 360, which has a 32 bit word. The difference in word size is crucial because Ship II uses so much bit packing (see section III. F). The input data is initially bit packed by the input data programs and is then retrieved during program execution whenever the data is used by the program. Transfer of Ship II would require modification in the bit-packing subroutines because of the difference in word size. Without these modifications, Ship II would be unusable on an IBM 360. Modification of Ship II to run on an IBM 360 would require approximately 6 man months, a cost which does not seem excessive in view of the potential uses of Ship II. However, these advantages can only be realized if the users of Ship II (NAVPERSRANDLAB) can become more aware of real, current Navy manpower and personnel problems to which Ship II could be applied. The cost of modification would perhaps be excessive if Ship II were to be used only to study hypothetical problems or to collect data by which to further evaluate the model.

If the problem of finding problems and users for Ship II can be solved, then other factors weigh heavily in favor of modifying Ship II for the IBM 360. The IBM 360 is much larger than the CDC 3800 currently being used; core storage on the 360 is 1.5 million bytes, which is equivalent to about 375,000 words of core storage. The CDC 3800 now being used has 57,000 words. Because of the larger core storage, Ship II as modified for the IBM 360 would use neither bit packing nor overlays. Elimination of the extensive use of these techniques which characterize the current version of Ship II would reduce running time by at least a factor of two. In other words the modified version of Ship II would run at least twice as fast, which would reduce cost of using the model. In addition, however, the reduced complexity of the model would increase the model flexibility. Ship II could be enlarged for use on larger ships using larger crew sizes and equipment. Other modifications to the model could be made, if needed. The modified version of the model would therefore be less expensive to operate and would be more flexible in the types of problems it could be applied to.

So far this section has discussed the issues related to whether or not Ship II should be reprogrammed. Another course of action, however, can be taken. Certain sections of the model can be initially modified and decisions on modification of the entire model can be postponed until more information is available. Ship II is constructed in a modular fashion; each shipboard function in the model is contained in a separate subroutine. Each of these subroutines could form the basis for a smaller, more detailed model, which would have two advantages: (1) the construction of new models would be facilitated, and (2) if a decision is made to no longer use Ship II, the model could live on in the form of smaller, more usable models. The time and effort spent to develop Ship II would therefore not be totally wasted. This alternative seems to be a reasonable course of action in the present situation.

The first priority for effective use of Ship II is to establish coordination between Ship II personnel and project managers who could sponsor the use of Ship II and assist in identifying and collecting input data. While this type of coordination is being established, selected sections of Ship II could be modified for IBM 360 and used to form the basis for new models as described above. Thus the construction of new models could be facilitated.

An alternative course of action may be available for using Ship II in San Diego. If a CDC 3800 is available for use in San Diego, then Ship II could be used there in its present form. Potential disadvantages of this alternative are difficulty in establishing necessary coordination, if the CDC 3800 is located in a Navy organization, or high computer costs, if computer time is purchased commercially. In either case, none of the advantages of using Ship II on a larger computer would be available. However, if Ship II will be used only infrequently after the new Center is formed, then this may be the most prudent alternative.

#### D. Further Evaluation of Ship II<sup>2</sup>

The studies reviewed in Chapter II have provided a large amount of data about Ship II; but the data have not been sufficient for an in-depth evaluation of the model on all the criteria discussed in Chapter III. This section will briefly

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<sup>2</sup> Much of this section is based on Messer (1973).



discuss work which would contribute to further evaluation of Ship II. Given the potential of Ship II to contribute significantly to the Navy manpower planning process, the resources needed to perform further evaluation appear to be small in comparison to the benefits which would result from knowing the validity, reliability, and sensitivity of the Ship II inputs and outputs.

### 1. Predictive Validity

As discussed earlier in this report, Ship II is a complex model with many input and output variables. The validation process would be to run Ship II for various combinations of input and output variables and to compare the results with actual "real world" data. The exhaustive testing of all input and output combinations with a model the size of Ship II would be virtually impossible. But, further steps can be taken to evaluate the validity for specific applications of Ship II.

Although many statements have been made as to the "lack of real world data" and to the "high cost of obtaining real world data", adequate documentation has not yet been presented that it is impractical to obtain real world data which could be used in evaluating the predictive validity of Ship II. Siegel (1973) believes that "the difficulty of developing predictive validity data for such models in a Navy context does not represent an entirely acceptable reason for failure to develop such data." (p.8)

The first task in improving the evaluation of Ship II with regard to predictive validity would be to determine the practicality of obtaining real world data to compare with the results of simulations using Ship II for specific purposes. The "specific purposes" would be based on high priority Navy manpower problems. For each specific purpose, the following steps should be undertaken:

- a. Identify the types of real world data needed to evaluate the predictive validity of Ship II.
- b. Identify potential sources of data.
- c. Identify deficiencies and gaps in these sources.
- d. Identify resources (time, people, money) needed to correct deficiencies and/or fill gaps.

- e. Develop the criteria for deciding whether collecting real world data is practical.

If it is determined that it is practical to collect real world data, then they should be collected and compared to the results of the Ship II simulation and used in evaluating the predictive validity of Ship II. If it is determined that real world data collection is not practical (e.g., data unavailable and/or too costly to obtain), then the reasons why data collection is not practical should be carefully documented. In the latter case, a less rigorous means of evaluation of predictive validity can be used, based on what VanHorn (1971) calls a "Turing test." VanHorn describes a Turing test as follows:

"The test is simple. Find people who are directly involved with the actual process. Ask them to compare actual with simulation output. To make the test a little more rigorous, one might offer several sets of simulated data and several sets of actual data and see if the "experienced" people can tell which is which. One might even test the classification for statistical significance. If people can discriminate, ask them how they do it. The experimenter can then decide if the detectable difference affects the inferences that he wishes to make.... The idea is certainly appealing and deserves further exploration. It is probably a great improvement over having the modeler use his intuition to validate his model. However, whether one can make meaningful statements on the power of such a test is an open question." (p. 252-253).

Another approach to testing predictive validity of Ship II would be to push the model to its limits by using it for unrealistic purposes (e.g., determine the effects of cutting manpower on a class of destroyers by three-quarters) to determine if the model has predictive validity for wide ranges of input variable values. In these cases where extreme values are used for input variables, real world data would not be available to use as a comparison point for the results obtained from using Ship II simulation. In these cases, a judgmental evaluation of the predictive validity of Ship II should be made by comparing both the magnitude and the direction of the change in dependent variables due to changes in independent variables observed in the simulation to the expected magnitude and direction of changes in the real world.

## 2. Reliability

Further evaluation of Ship II is needed with regard to two types of reliability:

- The reliability of the variances of the output variables in the simulation model as compared to the variances in the real world.
- The reliability (or consistency) of the results of Ship II when it is applied by different users.

With regard to the reliability of the variances, the same comments apply as to the previous discussion of predictive validity. Although it has been stated many times that real world data on the variances are not available or that obtaining real world data on the variances would be "too costly", adequate documentation has not yet been presented that it is impractical to obtain real world data on variances which could be used to evaluate the reliability of Ship II.

For such specific past or future use of Ship II simulation, the following steps should be taken to attempt to evaluate the reliability of Ship II:

- a. Identify the types of real world variance data needed to evaluate the reliability of Ship II (e.g., the variance of deferrals for parts and assistance).
- b. Identify potential sources of data.
- c. Identify deficiencies and gaps in these sources.
- d. Identify resources (time, people, money) needed to correct deficiencies and/or fill data gaps.
- e. Develop the criteria for deciding whether collecting real world variance data is practical.

If it is determined that it is practical to collect real world variance data, then they should be collected and compared to the results of the Ship II simulation and used in evaluating the reliability of Ship II. If it is determined that real world data collection is not practical (e.g., data unavailable and/or too costly to obtain), then the reasons why data collection is not practical should be carefully documented.

The reliability (or consistency) of the results of Ship II when it is applied by different users has yet to be tested. One of the features of Ship II is its supposed adaptability to other classes of ships besides destroyers. If further testing of Ship II is undertaken, it would be useful to:

- Estimate the extent of the modifications needed to use Ship II for other classes of ships.
- Estimate the resources (time, people, money) needed to make the modifications.

If it is, in fact, feasible to utilize Ship II for other classes of ships and the model is run for those other classes, the reliability (consistency) of the results of Ship II when it is applied by different users could be tested by comparing the output values, and the variances of those output values, of Ship II obtained from the various classes of ships by running the model for the same purpose (e.g., reduced manning studies) for those systems which are the same on both classes of ships.

### 3. Sensitivity

Further evaluation of Ship II is needed with regard to sensitivity. As discussed in Chapter III and IV of this report, the data available from the previous Ship II studies were usually not appropriate for evaluating sensitivity. Sensitivity was defined as "the degree to which the dependent variables in a model are responsive to the changes in values of the independent variables." Another way of expressing the same concept is to define sensitivity as the degree to which the results of using the simulation model depend upon the key assumptions made in the simulation model logic. It is extremely useful to know the degree to which dependent variables are sensitive to changes in key independent variables. For example, if the results of a simulation run for a particular purpose are very sensitive to only a few of the key assumptions in the model logic; i.e., the results depend only on a few of the input variables, this would raise the question whether it were necessary to use as complex a model as Ship II for that particular purpose.

In future Ship II studies, the following steps should be taken to test the sensitivity of Ship II:

- Identify what are assumed to be the key assumptions in the Ship II simulation model logic (these would depend upon the particular application of Ship II).
- Run the model for various values of the input variables which comprise these key assumptions.
- Indicate the degree to which the predictive validity of Ship II changes for particular applications in response to changes in the key assumptions in the model logic; i.e., indicate the key assumptions to which the results of the simulation are sensitive.

#### 4. Utility

Further evaluation of Ship II is needed with regard to utility. In Chapter III of this report, the four general classes of Ship II applications are discussed:

- a. Manning information
- b. Equipment information
- c. Task and training information
- d. Operations requirements information.

Although the four classes of applications encompass a range of problems which could make Ship II a potentially useful tool, an exhaustive list of the potential users, their potential uses of the model to solve particular problems, and the existence of any alternative ways to solve these problems has not been developed. This information is necessary when justifying the further development and use of such a highly complex model which has entailed significant development costs to date and which may entail further development costs in the future.

The following steps should be undertaken to determine more precisely the utility of Ship II:

- Develop an exhaustive list of potential users (and uses) of Ship II by surveying relevant organizations in both the sea and shore naval establishments.

- Determine if the potential uses of Ship II to solve particular problems require a model as sophisticated as Ship II.
- Determine if other, less complex methods, which are valid, reliable, and less costly, could be utilized instead of Ship II.

## 5. Practicality

Further evaluation of Ship II is also needed with regard to practicality. In Chapter III of this report, five factors are responsible for the practicality of Ship II.

- a. Costly and time-consuming input data preparation.
- b. Complex computer programs which users may need to understand.
- c. Current compatability of Ship II only with the CDC 3800 computer.
- d. High operating costs.
- e. Current inability of users to select output report formats.

In Chapter IV, it is stated that even though the "practicality of Ship II is low, so is the practicality of most other alternative methods for studying the same problems as Ship II." However, these alternative methods and their degree of practicality have not been listed or discussed in detail. Again, this information is necessary when justifying the further development and use of this complex and costly model.

The following steps should be undertaken to determine more precisely the practicality of Ship II:

- Determine the practicality (cost, complexity, and so forth) of alternative methods to Ship II for specific uses and compare with the practicality of Ship II.
- Based upon the practicality comparison and the utility criteria, determine if further studies to better determine the validity, reliability, and sensitivity of Ship II are justifiable.

## E. Relationship Between Ship II and Other Navy Models

Previous sections of the report have argued that, even though the technical characteristics of Ship II are not completely known, the utility of the model is sufficiently high that further study and use of Ship II is justified. An additional factor related to this question is whether the Navy has other, better models which can be used instead of Ship II. A comprehensive survey of Navy manpower and personnel models has just been completed (Hutchins, Prather, Barefoot, Flint, & Letsky, 1973). One hundred and one Navy models, including Ship II, were reviewed and categorized into one of six categories. These categories comprise all of the types of manpower and personnel models which are needed to form an integrated and comprehensive manpower planning system.<sup>2</sup> Ship II was classified as a stochastic Productivity Measurement Model. Only eight other Navy models were also classified as the same type of model. Only four of these, including Ship II, are ship models.<sup>3</sup> Thus only three other simulation models can potentially be used in place of Ship II.

### 1. Description of Ship II and Alternative Models

Each of these models will be listed below, together with a description of model objective, primary inputs and primary outputs.<sup>4</sup> The same information<sup>4</sup> will then be listed for Ship II.

#### a. Siegel-Wolf Two Man Operator Simulation Model

(1) Model Objective - To predict via digital simulation the likelihood of successful man-machine performance and to give equipment designers quantitative answers to operator overload/underload conditions and the effect of operator speed and stress on system performance.

(2) Primary Inputs - Operator proficiency; task sequence; mission time; stress threshold; parameters.

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<sup>2</sup>The categories are discussed in Hutchins, et al (1973), pp. 56.

<sup>3</sup>The other three models are general man-machine models which can be applied to many kinds of man-machine systems.

<sup>4</sup>taken from Hutchins, et al (1973), Appendix A, pp. A475-A482.



(3) Primary Outputs - Percent success; tasks ignored/failed; time spent on tasks; time spent waiting; average and peak stress.

b. Digital Computer Simulation Model for Intermediate Size Crews

(1) Model Objective - To predict via digital simulation the operation of man-machine systems by crews of from 4 to 20 men.

(2) Primary Inputs - Scheduled events from task analyst, documentation, interviews; equipments as specified in ship/activity allowance; personnel; emergencies; parameters.

(3) Primary Outputs - Work unit detail; daily report; iteration report; run summaries.

c. Large Group Oriented Crew Behavioral Simulation Model

(1) Model Objective - To predict via digital simulation the man-machine system efficiency and related equipment and performance measures as a function of crew composition, working levels and stress imposed by the mission.

(2) Primary Inputs - Equipment; personnel data; parameters; constants and mission data.

(3) Primary Outputs - Work out detail; daily report; iteration summary and run summary.

d. Ship II

(1) Model Objectives - To simulate manpower related variables for total ships for research in manpower questions.

(2) Primary Inputs - Manning (billets, organization), watches (acquired from SMD or proposed manning; Equipment data (MTBF, CM, PM) (acquired from SMD, work study); Operational scenario (acquired from deck logs, Type Commanders Instructions).

(3) Primary Outputs - Manpower utilization (man-hours by each man in task areas); equipment data (failures, downtime); task data (tasks done, postponed, or canceled); readiness (equipment and total ship).



## 2. Comparison Between Ship II and Alternative Models

The information in the previous paragraphs shows that none of the three alternative models is designed to perform the same functions which Ship II performs. These models are useful and well constructed, but they simply cannot study the range of problems which Ship II can study nor can they provide the rich variety of output data which Ship II provides. The Navy has no other models which can be used in place of Ship II for most of the problem areas Ship II was designed to study. Ship II is, in fact, unique.

## VI. RECOMMENDATIONS

1. Ship II is a potentially useful manpower planning tool which has capabilities not available in any other Navy model. An effort should be made to inform the Navy manpower planning community about Ship II characteristics, uses, and how the model interfaces with other manpower planning models, such as the Manpower Determination Model (MDM). Special care should be taken to inform potential users that Ship II is not, and was not designed to be, a replacement for MDM or other such models. Instead of competing with present manpower study methods, Ship II provides an additional capability which could provide valuable support to Navy manpower planners.
2. Additional studies to further evaluate Ship II should be done. Validity should be of primary importance in these studies, followed by sensitivity and reliability. Additional data on utility of Ship II for specific problems of current interest to the Navy, and practicality of Ship II relative to other competing methods would also be valuable. The validity, sensitivity and reliability studies should be conducted within the context of specific problem areas identified in the utility studies. Performance of all evaluation studies should depend on indications of acceptance of Ship II by Navy manpower planners.
3. Ship II should be transferred to the new Navy Personnel Research and Development Center and modified to run on the Center computer. A feasible alternative to this recommendation may be to keep Ship II in its present form if the use of a CDC 3800 can be obtained in the San Diego area at reasonable cost. If neither of these actions is taken, the result would be that San Diego would have the simulation function and the personnel, but no computer facility; Washington, on the other hand, would have an appropriate computer facility but no personnel or simulation functions. The result might be that Ship II would simply die of disuse.

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## APPENDIX A

### A. Introduction

This section contains a listing and description of each input data element. Input data to the model are entered via special forms specifically designed for the SHIP II model. Seventeen different forms are used and, with the exception of GENERAL DATA, each represents a different card type. Fifteen card types are used for GENERAL DATA.

The different forms are:

<u>FORM</u>	<u>CARD</u>	<u>TYPE</u>
GENERAL DATA	00 --	14
RATING MASTER LIST		20
NEC MASTER LIST AND EQUIVALENTS		21
SHIP DIVISIONS AND DIVISIONAL TRAINING		25
PERSONNEL LIST		26
WATCH STATION MANNING		27
SUBSYSTEM IDENTIFICATION		30
EQUIPMENT DATA		31
TROUBLESHOOT (C M)		32
REPAIR/TEST (C M)		33
PLANNED MAINTENANCE (P M)		34
TOOLS INVENTORY		35
FACILITIES MAINTENANCE (F M) AND SUPPORT AND MAINTENANCE		40
TRAINING EXERCISE REQUIREMENTS		50
TOTAL SHIP READINESS SCORING		60
MISSION FUNCTION READINESS SCORING		61
EMPLOYMENT SCHEDULE		90

In the following, each of these forms is presented along with a description of the individual entries. In each case, sample data entries

have been made to aid the user in understanding the format of each element. The sample data shown were used to check out the model, and correspond to the sample output data shown in section V.

#### FORMAT CONVENTIONS

The following conventions are applicable to all data entries.

1. All times are entered in hours, unless otherwise noted.
2. All ratings are left adjusted, and all rates are right adjusted.
3. All numeric fields are right adjusted.
4. Blanks are interpreted as zeros.

## **B. Input Forms**

### **1. GENERAL DATA**

CARD TYPES, 0 through 14, GENERAL DATA, contain a series of constants related to table sizes, parameter variations and work day constraints. The individual elements are discussed below.

<b>NO. OF DIFF. RATINGS</b>	The number of different skill types (ratings) aboard. This number should correspond to the number of ratings in the Rating Master List (Card Type 20).
<b>NO. OF DIFF. NECS</b>	The number of different Naval Enlisted Classifications (NEC) aboard. Corresponds to the NEC Master List (Card Type 21).
<b>NO. OF DIVISIONS</b>	The number of different divisional organizations aboard (Card Type 25).
<b>NO. OF WATCH STATIONS</b>	The total number of watch stations at General Quarters (Card Type 27).
<b>NO. OF SUBSYSTEMS</b>	The total number of subsystems represented by the ship's equipment. This value is used to read subsystem related data (Card Type 30).
<b>NO. OF TOOL TYPES</b>	The number of different special tools and test equipment used in the performance of maintenance (Card Type 35).
<b>NO. PF FM-S/A JOBS</b>	The total number of different Facilities Maintenance and Support/Administrative jobs (Card Type 40).
<b>NO. OF TRAINING EXERCISE TYPES</b>	The number of different types of exercises which can be scheduled (Card Types 50 and 90).

NO. OF TOTAL SHIP SCORING DECISIONS	The number of decisions used to score the readiness of the total ship ( Card Type 60).
RANDOM NUMBER SEED	A number which initiates the sequence of random numbers. A different number will result in a different series.
NO. OF MISSION FUNCTIONS	The number of subsystems which are designated as mission functions.
TOTAL NUMBER OF MEN	The number of men comprising the crew.
SUBSYSTEMS WHICH ARE MISSION FUNCTIONS	The subsystem numbers which are designated as mission functions.
PLANNED MAINTENANCE NO.	The number of each type of Planned Maintenance jobs ( Card Type 34).
CANCEL AFTER	The length of time a Planned Maintenance job can be delayed before it is cancelled.
STANDARD NAVY WORK WEEK	
WATCHSTANDERS	The standard Navy Work week for Watchstanders at-sea.
NON-WATCHSTANDERS	The standard Navy Work week for non-watchstanders at-sea.
PARAMETER VARIATION RATIOS	Factors which can be used to alter variables on the model parameters. If set to 1.0 no change will occur; 0.8 represents a 20% reduction; and 1.2 represents a 20% increase. The model parameters which correspond to the PVR's are listed in Table II.



TABLE II

## Parameter Variation Ratios

PVR	Card Type	Variable Ident.	Data Maximum
1	25	Session Duration	40.95 hours
2	25	Hours/Week/Man	40.95 hours
3	30	Fail Detect. Time Cond. I	10.23 hours
4	30	" " " " III	10.23 hours
5	30	" " " " IV	10.23 hours
6	30	" " " " V	10.23 hours
7	30	" " Prob. During PM	100%
8	31	Op. % at Cond. I	100%
9	31	" " " " III	100%
10	31	" " " " IV	100%
11	31	" " " " V	100%
12	31	MTBF	10,485.75 hours
13	31	Prob. Degradation	100%
14	31	Defer for Assist: Prob.	100%
15	31	" " " Mean	10,485.75 hours
16	31	" " " Stan. Dev.	10,485.75 hours
17	31	Defer for Parts: Prob.	100%
18	31	" " " Mean	10,485.75 hours
19	31	" " " Stan. Dev.	10,485.75 hours
20	32	Time in Func.: Mean	167,772.15 hours
21	32	" " " Stan. Dev.	167,772.15 hours
22	32	Error Prob: P1	100%
23	32	" " P2	100%
24	32	" " P3	100%
25	32	" " P4	100%
26	32	Delay Time (DT)	655.35 hours
27	33	Time in Func.: Mean	167,772.15 hours
28	33	" " " Stan. Dev.	167,772.15 hours
29	33	Error Prob.: PD	100%
30	33	" " P2	100%
31	33	Probability - PTR/PTR	100%
32	34	Time in Func: Mean	167,772.15 hours
33	34	" " " Stan. Dev.	167,772.15 hours
34	40	Manhours/day	167,772.15 hours
35	40	% Carry	100%
36	Unused		
37	Unused		
38	Unused		

**JOB ASSIGNMENT WORK  
DAYS**

Times which represent the beginning and end of the work day for each of the job types listed. Assignments will not be made before the values labled "DON'T ASSIGN BEFORE" or after "DON'T ASSIGN AFTER". The job types are:

FM	Facilities Maintenance
S/A	Support/Administrative work
DIV TRAIN	Divisional Training
PM-PORT	PM jobs designated as performed in-port.
NOT DAILY	PM jobs with frequencies other than Daily.
DAILY	Daily PM jobs
PM SEA/PORT	PM jobs designated as performed at-sea or in-port.
CM	Corrective Maintenance
NON CRIT	Non-critical corrective maintenance
CRIT	Critical corrective maintenance jobs

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best available copy.

## 2. RATING MASTER LIST

CARD TYPE 20 contains a list of each rating represented in the Watch Bill, or expected to be on board. Where a rating has an equivalent which would be used in reassigning jobs, that rating should be listed in the equivalent rating column. Primary ratings should be listed in alphabetical order. Up to 75 different ratings can be entered: it is advisable to list all possible ratings since this information is used to screen other input data for erroneous entries. For example, if in the Personnel List a rating is called for which is not entered on card type 20, an error will result.

SEQUENCED RATING  
(75)

A list of all ratings to be found on  
board. Limit = 75.

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Seq- -ences	Equi- -valence
1	1
2	2
3	3
4	4
5	5
6	6
7	7
8	8
9	9
10	10
11	11
12	12
13	13
14	14
15	15
16	16
17	17
18	18
19	19
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87	87
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89	89
90	90
91	91
92	92
93	93
94	94
95	95
96	96
97	97
98	98
99	99
100	100

### 3. NEC MASTER LIST AND EQUIVALENTS

CARD TYPE 21 is a sequential listing of the NEC's (Naval Enlisted Classification) which are held by members of the crew. Also listed is an equivalent NEC, if one exists. Equivalent NEC's are generally held by higher rates whose NEC's absorb lower NEC's. The equivalence table is provided for job reassignment in the event the specified NEC is occupied.

SEQUENCED NEC's

A list of all NEC's aboard ship.

(75)

EQUIVALENT NEC

An NEC which is equivalent to the one identified in the list of sequenced NEC's.

(75)

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NEC MASTER LIST AND EQUIVALENT					
NO SEQUENCE OF NEC'S		EQUIVALENT Nec. If any		CARD TYPE	
1	2	3	4	5	6
335					21
413					21
451	1	487			21
487					21
987					21
1128					21
1135					21
1509					21
1544					21
1547					21
1579					21
2304					21
2342					21
2516					21
4517					21
4613					21

#### 4. SHIP DIVISIONS AND DIVISIONAL TRAINING

##### CARD TYPE 25,

is a sequential listing of divisions which provides division name, the number of personnel in each division, and divisional training data. Divisional training data include session duration, rescheduling intervals, minimum class size and hours per week per man of required divisional training.

DIV NO  
(20)

The identification number of the division. This number should be identical to other division numbers entered elsewhere in the input data.

DIVISION NAME

A sixteen character field which contains the name of the division. This name is used for output identification only.

NO. OF MEN

The number of men in the division.

SESSION DURATION  
(HRS.)

The length of a divisional training session. This figure is used as a constant and all sessions are of this length (not randomized).

INTERVAL BETWEEN  
ATTEMPTS TO  
SCHEDULE (HRS.)

If an occasion arises when divisional training cannot be held, the activity is rescheduled. This value represents the amount of time to wait before attempting a reschedule.

MIN. MEN PER  
SESSION

The minimum number of men which can constitute a training session. Unless this number of men are available the session will be delayed.

HOURS/WEEK/MAN

Desired training for each man each week.



# SHIP SIMULATION MODEL INPUT

## NAVAL PERSONNEL RESEARCH AND DEVELOPMENT LABORATORY

SHIP DIVISIONS AND DIVISIONAL TRAINING							
DIV NO.	DIVISION NAME	Number of men	Session Duration (Hours)	Scheduling Interval (Hours)	Minimum Attendance	Hours per week	Page
1	1 W DIVISION	4	.75	1.0	2	1.0	25
2	2 OC DIVISION	4	.75	1.0	2	1.0	25
3	3 OE DIVISION	3	.75	1.0	2	1.0	25
4	4 OI DIVISION	3	.75	1.0	2	1.0	25
5	5 SECOND DIV	4	.75	1.0	2	1.0	25
6	6 F DIVISION	4	.75	1.0	2	1.0	25
7	7 A DIVISION	3	.75	1.0	2	1.0	25
8	8 FIRST DIV	4	.75	1.0	2	1.0	25
9	9 M DIVISION	4	.75	1.0	2	1.0	25
10	10 B DIVISION	4	.75	1.0	2	1.0	25
11	11 R DIVISION	3	.75	1.0	2	1.0	25
12	12 S DIVISION	4	.75	1.0	2	1.0	25

## 5. BILLET IDENTIFICATION AND AUG./EVOL. STATION ASSIGNMENT

CARD TYPE 26, lists, for each man aboard ship, his billet title, skill and NEC identification and whether or not he is assigned to a station for watch augmentations or evolutions. This card differs from card type 27; on card type 27 the title is associated with a station, not a billet title.

DIV NO (20)	Division number (1 through "N")
MAN NO (350)	The sequential number of the man in the division (same as card type 27). Numbering starts over with each division.
BILLET TITLE	The title of the billet. Any designation may be used.
SKILL-RATING	The rating of the man, if rated. If he is not rated, leave blank.
SKILL-RATE	Skill level of the man.
NEC (PRIMARY)	The man's primary Naval Enlisted Classification (NEC).
NEC (SECONDARY)	The man's secondary NEC, if he has one.
AUGMENTS	Watches can be augmented for training exercises. Up to five different augmentations are possible. A "1" entered in one of these columns means that the man will be placed on Watch (Training Exercise) if that augmentation is called for by

a Training Exercise. Examples of augmentation are I-ASW and I-AAW.

## EVOLUTIONS

Up to 20 different types of evolutions are possible. Evolutions are scheduled as part of the employment schedule. As with Watch Augmentations, a "1" in any column means that that man will be assigned to a station for that evolution. Simultaneous evolutions are not allowed except by combining the stations and identifying the combination as one evolution. Training Exercises and Evolutions cannot occur simultaneously.

# SHIP SIMULATION MODEL INPUT

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## 6. WATCH STATION MANNING

CARD TYPE 27 identifies the manning of watch stations for each of the primary readiness conditions. Each watch station on the ship is listed and identified with a title. The manning of that station is identified for conditions I, III, IV, and V. If the station is not manned at one or more of these conditions, the field is left blank. The personnel who man the station are identified by division number and man number within that division. Watch sections are also identified.

### STATION NUMBER (350)

A station is a position on the ship which is manned around the clock in at least one of the four primary readiness conditions. All such stations are listed and numbered in a sequential manner. This station number is used as an index for assigning personnel.

### STATION TITLE

A sixteen character field which contains the title of the station. Any appropriate title may be used.

### READINESS CONDITION MANNING ASSIGNMENTS

If a station is manned during one of the four readiness conditions, the assigned man is designated by his division and man number (card type 26). A division and man number is given for each section, or shift. Condition I has only one section and so relief is not required. Conditions III and IV have three sections and condition V has four. The sections in condition V are known as duty sections.

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**A-19**

# SHIP SIMULATION MODEL INPUT

## NAVAL PERSONNEL RESEARCH AND DEVELOPMENT LABORATORY

WATCH STATION MANNING													
READINESS CONDITION MANNING ASSIGNMENTS													
STATIONS													
STATION TITLE													
I													
II													
III													
IV													
V													
SECTIONS													
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## 7. SUBSYSTEM IDENTIFICATION

CARD TYPE 30 contains data on the name of each subsystem as well as failure detection times and probabilities, the number of equipment items it includes, and the number of readiness decisions entered on card type 61. A subsystem may or may not be a mission-oriented function. The subsystem numbers of the mission functions are defined on the General Data Card. If a subsystem is not a mission-oriented function, the entries related to readiness decisions are not required.

SUB SYS NO (100)	The sequential number of the subsystem.
SUBSYSTEM NAME	A sixteen character field which contains the name of the subsystem. Any appropriate name may be entered.
FAILURE DETECTION TIME	The expected time in hours between the occurrence of a malfunction and the detection of that malfunction by the crew. Four values may be entered, one for each of the four basic readiness conditions.
FAILURE DETECTION- PROB. DURING PM	The probability that an undetected failure in a subsystem will be detected during a planned maintenance action.
NO. EQUIP. ITEMS	The number of equipment items within the subsystem.
NO. READINESS RATING DECISIONS	The number of readiness decisions for each of the four readiness states (C1, C2, C3, C4) entered on card type 61 for mission-oriented subsystems.

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SUB SYS NO.	SUBSYSTEM NAME	FAILURE DETECTION										NO EQUIP ITEMS	NO READINESS RATING DECISIONS (EXCLUDED SUBSYS=0)				CARD TYPE
		TIME FOR CONDUCT (HRS)											C-1	C-2	C-3	C-4	
		I	II	III	IV	V	VI	VII	VIII	IX	X						
1	11AAW/SURVEILLANCE	0	.10	.25	1.0	50	2	1	1	1	1	1	1	1	30		
2	2AAW/FIRE	0	.10	.25	1.0	50	2	1	0	0	0	0	0	0	30		
3	3AAW/OTHER	0	.10	.25	1.0	50	2	0	0	0	0	0	0	0	30		
4	4ASW/SURVEILLANCE	0	.10	.25	1.0	50	1	0	0	0	0	0	0	0	30		
5	5ASW/OTHER	0	.10	.25	1.0	50	1	0	0	0	0	0	0	0	30		
6	6SURFACE WARFARE	0	.10	.25	1.0	50	5	1	5	0	0	0	0	0	30		
7	7SUBW/OTHER	0	.10	.25	1.0	50	1	0	0	0	0	0	0	0	30		
8	8MOBILITY/PROPUL	0	.10	.25	1.0	50	3	1	0	0	0	0	0	0	30		
9	9MOBILITY/OTHER	0	.10	.25	1.0	50	1	0	0	0	0	0	0	0	30		
10	10CAC/CRITICAL	0	.10	.25	1.0	50	1	1	0	0	0	0	0	0	30		
11	11CAC/OTHER	0	.10	.25	1.0	50	3	0	0	0	0	0	0	0	30		
12	12DECK AND HULL	0	.10	.25	1.0	50	2	0	0	0	0	0	0	0	30		
13	13MTSC	0	.10	.25	1.0	50	4	0	0	0	0	0	0	0	30		

## 8. EQUIPMENT DATA

CARD TYPE 31 contains detailed reliability, failure effects, and logistics delay data for each item of equipment. Up to 500 items of equipment can be represented. In addition, a special data element is provided which designates which watchstanders do maintenance jobs, if called for.

SUBYS. NO. (100)	A sequential number identifying the subsystem (same as entered in card type 30).
EQUIP. NO. (Total must not be more than 500)	The equipment number within the subsystem. Numbering starts over with each subsystem. The last equipment number must correspond to the number of equipment items per subsystem entered on card type 30.
EQUIPMENT NAME	A sixteen character field which contains the subsystem name. Any appropriate name may be used.
WATCH STAT LOC. (IF APPL)	In some instances, a failure may occur in a system and the only qualified technician is standing watch. If he uses that equipment to perform his watch duties, the model is designed to assign him to its repair. If this policy is to be used, this value represents the watch station location, as identified on card type 26, which utilizes the equipment.
OPERATING % OF EQUIPMENT AT READINESS CONDITIONS	The percent of time the equipment operates during each of the four basic readiness conditions.

MTBF (HRS.)	The Mean Time Between Failure, based on operating hours, of the equipment.
PROB. DEGR.	The probability that a failure in the equipment would result in a degradation of the readiness of the associated mission function (subsystem).
CRITICAL	An indicator, 0 or 1, which designates the equipment as critical or non-critical. Critical equipment items are maintained any time a failure occurs and take priority over other jobs.
DEFERRALS FOR:	
ASSITANCE PROB.	The probability that repair of this equipment item will be deferred for outside assistance.
MEAN, STD. DEV.	The mean and standard deviation of the time spent in a deferral for assistance (hours).
PARTS - PROB, MEAN, STD. DEV.	Same as above, except the cause of deferral is lack of parts.

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SUB SYS. NO.		EQUIP. NO.	EQUIPMENT NAME	WATCH STAT LOC NO	EQUIPMENT DATA										DEFERRALS FOR:										CARD DEV. TYPE	
					OPERATING % OF EQUIPMENT READINESS CONDITION					MTBF (HRS)	PROB. DEGR.	ASSISTANCE			OPERATIONS			PARTS								
												PROB.	MEAN	STD DEV.	PROB.	MEAN	STD DEV.	PROB.	MEAN	STD DEV.						
					I	III	IV	V	PROB.												MEAN	STD DEV.	PROB.	MEAN		
13	1	1	ICENTRIF FAN	2	23 24 25	100	100	100	100	550	0	10	24	10	5	100	1031									
13	2	2	2VENT CNTRL SYS			100	100	100	250	0	10	24	10	5	100	1031										
13	3	3	3TYPEWRITER			0	100	100	500	0	10	24	10	5	100	1031										
13	4	4	4ADDING MACHINE			0	100	100	500	0	10	24	10	5	100	1031										

## 9. TROUBLESHOOT (CM)

CARD TYPE 32 contains the data relative to the task of isolating the fault in a given item of equipment, given that a failure has been detected. The troubleshoot data include task time, personnel and test equipment requirements and measures related to the probability of successful fault isolation. Data are entered for each item of equipment designated on card type 31.

SUBYS. NO.	The subsystem number.
EQUIP. NO.	The equipment number.
DIV. RESP.	The division which contains the personnel responsible for maintaining the equipment. If a blank is entered, no constraint on division assignment is made.
TIME IN FUNCTION MEAN, STD. DEV.	The mean and standard deviation of the time required to isolate a malfunction in the equipment. A log normal distribution is presently used to randomize the actual time using Monte Carlo methods.
MEN	A set of data related to the personnel required to troubleshoot the equipment.
NEC (IF REQ. )	If special schooling is required to qualify for troubleshooting, the appropriate Naval Enlisted Classification is entered (NEC). If called out on card type 21, equivalent NEC's may be assigned if the original NEC is not available, and upward absorption is specified.

**NO, RATING, RATE**

Up to four different ratings can be used in a troubleshooting team. NO refers to the number of each rating and RATING and RATE are self explanatory.

**NO. UP.**

In the event the specified skill is unavailable, the model is designed to assign work to higher skill levels. NO. UP. is the number of rates higher than the one specified to which the job can be assigned. If the number is greater than the number of higher rates, the search will end with the highest rate.

**EQUIPMENT (TOOLS)**

Up to three different types of test equipment or special tools can be used on a job.

**NO**

Refers to the number of tool type  $i$  ( $i = 1, 2$  or  $3$ ) required.

**TYPE**

Refers to the type of tool required.

**ERROR PROBABILITIES**

(See Chapter III, Section 2a, Pages 27-31 for a definition and discussion of error probabilities).

**P1**

The probability that a type I error will occur in Troubleshoot.

**P2**

The probability that a type II error will occur in Troubleshoot.

**P3**

The probability that a type III error will occur in Troubleshoot.



PT

The probability that a type t error will occur in Troubleshoot.

DT

The average duration of a t error.

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TROUBLESHOOT (CM)																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																			
SUB SYS. NO.	EQUIP NO.	DIV RESP.	TIME IN FUNCTION			MEN						EQUIPMENT (TOOLS)						ERROR PROBABILITIES %					DT	CARD TYPE																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																											
			MEAN	STD DEV.	NEC (IF REQ)	NO	RATING	RATE	C-RATING	RATE	C-RATING	RATE	C-RATING	RATE	C-RATING	RATE	C-RATING	P1	P2	P3	P4	P5			P6	P7	P8	P9	P10	P11	P12	P13	P14	P15	P16	P17	P18	P19	P20																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																												
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## 10. REPAIR/TEST (CM)

CARD TYPE 33 contains data relative to the repair and repair verification of each equipment item. The data elements on this card are similar to the Troubleshoot data elements (card type 32), except for maintenance error probabilities. Also, a special element, PTR PTR (Probability that Troubleshoot is Required Prior to Repair), allows the user to designate the percentage of time that troubleshooting can be skipped.

SUBSYS. NO.	Subsystem number.
EQUIP NO.	Equipment number.
DIV RESP.	The division which contains the personnel responsible for the repair of the equipment. If left blank any qualified man aboard ship can be assigned.
TIME IN FUNCTION MEAN STD. DEV.	The mean and standard deviation of the time to repair and test the equipment. A log normal distribution is presently used to randomize this time via Monte Carlo methods.
MEN EQUIPMENT (TOOLS)	See associated description with card type 32.
ERROR PROBABILITIES	
PD	The probability of a type d error.
P2	The probability of a type II error.
PTR PTR	The probability that troubleshoot is required prior to repair..

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## 11. PLANNED MAINTENANCE (PM)

CARD TYPE 34 contains all of the data necessary to execute planned maintenance during a simulation. The data are based on the Navy's Planned Maintenance System (PMS), and more specifically the Maintenance Index Pages of the PMS system. Each entry on card type 34 becomes a separate job in the simulation which is executed at the specified frequency.

### FREQ.

Frequency of the planned maintenance action. Allowable frequencies are:

- D Daily
- W Weekly
- M Monthly
- Q Quarterly
- S Semi-annually
- A Annually

All PM actions with the same frequency are listed together beginning with Dailys and ending with Cyclics.

PM INDEX (FOR EACH CAT.) (Total of all types must be less than 1000)

A sequential numbering of each action within a given category (Daily, Weekly, Monthly, etc.).

SUBSYS. NO

Subsystem number (does not have to be in order).

EQUIP NO

Equipment number (does not have to be in order).

DIV. RESP.

The division which contains the ratings required to perform the job. If blank, any

qualified personnel will be assigned regardless of division.

TIME IN FUNCTION  
MEAN, STD. DEV.

The mean and standard deviation of the time required to perform the job.

MEN/EQUIPMENT  
(TOOLS)

See card type 32 for a description of these entries.

SEA/PORT

An index which indicates whether the job must be done in port. If equal to p the job must be done in port. Otherwise it may be performed at any time.

CYCLE TIME

No longer used.





# SHIP SIMULATION MODEL INPUT

## NAVAL PERSONNEL RESEARCH AND DEVELOPMENT LABORATORY

PLANNED MAINTENANCE (PM)																			
PM INDEX (FOR EACH CAT)	SUB. SYS. NO.	EQUIP. NO.	DIV. RESP.	TIME IN FUNCTION		NEC	MEN				EQUIPMENT (TOOLS)				CYCLE TIME (FOR CYCLIC PM ONLY)	CARD TYPE			
				MEAN	STD DEV		RATING	RATE	RATING	RATE	RATING	RATE	TOOL INDEX	TOOL INDEX			TOOL INDEX	TOOL INDEX	
0 25	13	1	1	1.0	.1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
0 26	13	2	1	1.0	.1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
0 27	13	3	1	1.0	.1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
0 28	13	4	1	1.0	.1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
1 1	1	1	1	1.0	.1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
1 2	1	2	1	1.0	.1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
1 3	2	1	1	1.0	.1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
1 4	2	2	1	1.0	.1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
1 5	3	1	1	1.0	.1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
1 6	3	2	1	1.0	.1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
1 7	4	1	1	1.0	.1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
1 8	5	1	1	1.0	.1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
1 9	6	1	1	1.0	.1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
1 10	6	2	1	1.0	.1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
1 11	6	3	1	1.0	.1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
1 12	6	4	1	1.0	.1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
1 13	6	5	1	1.0	.1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
1 14	7	1	1	1.0	.1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
1 15	8	1	1	1.0	.1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
1 16	8	2	1	1.0	.1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
1 17	8	3	1	1.0	.1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
1 18	9	1	1	1.0	.1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
1 19	10	1	1	1.0	.1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
1 20	11	1	1	1.0	.1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

**NAVAL PERSONNEL RESEARCH AND DEVELOPMENT LABORATORY**

A -39

**NAVAL PERSONNEL RESEARCH AND DEVELOPMENT LABORATORY**

A - 40

# SHIP SIMULATION MODEL INPUT

NAVAL PERSONNEL RESEARCH AND DEVELOPMENT LABORATORY

PLANNED MAINTENANCE (PM)																														
PM INDEX (FOR EACH CAT)	SUB. SYS. NO.	EQUIP. NO.	DIV. RESP.	TIME IN FUNCTION		MEN				EQUIPMENT (TOOLS)				CYCLE TIME (FOR CYCLIC PM ONLY)	CARD TYPE															
				MEAN	STD. DEV.	1	2	3	4	1	2	3																		
													NO			RATING	RATE	NO	RATING	RATE	NO	RATING	RATE	NO	RATING	RATE				
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	
9	13	6	5	3	1.0	.1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	34
9	14	7	1	6	1.0	.1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	34
9	15	8	1	10	1.0	.1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	34
9	16	8	2	11	1.0	.1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	34
9	17	8	3	11	1.0	.1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	34
9	18	9	1	10	1.0	.1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	34
9	19	10	1	2	1.0	.1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	34
9	20	11	1	2	1.0	.1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	34
9	21	11	2	1	.1	.01	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	34
9	22	11	3	1	.1	.01	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	34
9	23	12	1	8	.1	.01	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	34
9	24	12	2	8	1.0	.1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	34
9	25	13	1	1	1.0	.1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	34
9	26	13	2	1	1.0	.1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	34
9	27	13	3	1	.1	.01	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	34
9	28	13	4	1	.1	.01	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	34
5	1	1	1	6	1.0	.1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	34
5	2	1	2	3	1.0	.1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	34
5	3	2	1	5	1.0	.1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	34
5	4	2	2	6	1.0	.1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	34
5	5	3	1	3	1.0	.1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	34
5	6	3	2	3	1.0	.1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	34
5	7	4	1	7	1.0	.1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	34
5	8	5	1	7	1.0	.1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	34

# SHIP SIMULATION MODEL INPUT

## NAVAL PERSONNEL RESEARCH AND DEVELOPMENT LABORATORY

PLANNED MAINTENANCE (PM)																									
PM INDEX (FOR EACH CAT)	SUB. SYS. NO.	EQUIP. NO.	DIV RESP	TIME IN FUNCTION		MEN										EQUIPMENT (TOOLS)					CYCLE TIME (FOR CYCLIC PM ONLY)	CARD TYPE			
				MEAN	STD. DEV	NEC	1 RATING RATE	2 RATING RATE	3 RATING RATE	4 RATING RATE	5 RATING RATE	6 RATING RATE	7 RATING RATE	8 RATING RATE	9 RATING RATE	10 RATING RATE	11 TOOL INDEX	12 TOOL INDEX	13 TOOL INDEX						
																			1	2			3		
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
5	9	6	1	3	1.0	.1	1ETR	34										11	21	45					34
5	10	6	2	3	1.0	.1	1ETR	34										11	21	45					34
5	11	6	3	3	1.0	.1	1ETR	34										11	21	45					34
5	12	6	4	3	1.0	.1	1ETR	34										11	21	45					34
5	13	6	5	3	1.0	.1	1ETR	34										11	21	45					34
5	14	7	1	6	1.0	.1	1FTMSM4											11	21	55					34
5	15	8	1	0	1.0	.1	1BT XM4											11	21	55					34
5	16	8	2	11	1.0	.1	1BT	24										11	21	55					34
5	17	8	3	12	1.0	.1	1BT	24										11	21	55					34
5	18	9	1	0	1.0	.1	1BT FM4											11	21	55					34
5	19	10	1	2	1.0	.1	IRM	34										11	21	45					34
5	20	11	1	2	1.0	.1	IRM SM4											11	21	45					34
5	21	11	2	1	.1	.01	IRM	34										11	21	45					34
5	22	11	3	1	.1	.01	IRM	34										11	21	45					34
5	23	12	1	8	.1	.01	IRM	34										11	21	45					34
5	24	12	2	8	1.0	.1	IRM XM4											11	21	45					34
5	25	13	1	1	1.0	.1	IRM FM4											11	21	45					34
5	26	13	2	1	1.0	.1	IRM FM4											11	21	45					34
5	27	13	3	1	.1	.01	IRM	34										11	21	45					34
5	28	13	4	1	.1	.01	IRM	34										11	21	45					34
A	1	1	1	6	1.0	.1	1FTM	34	1FTMSM4									11	21	5					34
A	2	1	2	3	1.0	.1	1FTM	34										11	21	5					34
A	3	2	1	5	1.0	.1	1FTM	34										11	21	5					34
A	4	3	2	6	1.0	.1	1FTM	34										11	21	5					34



# SHIP SIMULATION MODEL INPUT

## NAVAL PERSONNEL RESEARCH AND DEVELOPMENT LABORATORY

PLANNED MAINTENANCE (PM)																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																							
PM INDEX (FOR EACH CAT)	SUB. SYS. NO.	EQUIP. NO.	DIV. RESP.	TIME IN FUNCTION		MEN				EQUIPMENT (TOOLS)				CYCLE TIME (FOR CYCLIC PM ONLY)	CND TYPE																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																								
				MEAN	STD DEV	1	2	3	4	5	6	7	8			9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																		
														NEC																								RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE	RATING	RATE

**NAVAL PERSONNEL RESEARCH AND DEVELOPMENT LABORATORY**

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## 12. TOOLS INVENTORY

CARD TYPE 35 contains a list of the tools and test equipment and a count of the number of each type available aboard ship. These items can be called for by Troubleshoot, Repair/ Test and Planned Maintenance jobs.

TYPE (50)	A sequential number of each type of equipment.
DESCRIPTION	A sixteen character field containing a description of the tool/test equipment. Any appropriate designation may be used.
NO AVAIL.	The number of each type of tool/test equipment available aboard ship.

# SHIP SIMULATION MODEL INPUT

NAVAL PERSONNEL RESEARCH AND DEVELOPMENT LABORATORY

TOOLS INVENTORY		NO. AVAILABLE		TYPE
TYPE	DESCRIPTION	NO. AVAILABLE		
1	SCREWDRIVER	20		35
2	WRENCH	20		35
3	OSCILLOSCOPE	2		35
4	VOLT-Ohm METER	2		35
5	OIL CAN	5		35

**13. FACILITIES MAINTENANCE (FM) AND SUPPORT AND  
ADMINISTRATIVE (S/A)**

CARD TYPE 40 contains the data which describe the daily FM and S/A jobs required of the ship. Each entry represents an individual job which is assigned on a daily basis (excluding Sunday or Saturday in port).

JOB NO (105)	The sequential number of the job.
DIV RESP.	The division which is responsible for the work.
FM or S/A	FM if the job is Facilities Maintenance, S/A if the job is Support/Administrative.
DESCRIPTION	A sixteen character field which contains a description of the work. Any appropriate description may be used.
SKILL, RATING, RATE	The skill type and level to which the job should be assigned.
MAN HOURS PER DAY	The total man hours per day required to complete the job.
% CARRY	The amount of the daily work assignment which should be added to the following day's workload if not completed.

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[illegible]

## 14. TRAINING EXERCISE REQUIREMENTS

CARD TYPE 50 contains the data necessary to schedule and perform required training exercises. The input data are based on the requirement placed on destroyer type ships to maintain training readiness through periodic refresher exercises. The data include the frequency of each of the exercises, identification of special watch augmentations, and the mission functions which must be operational to perform the exercise. Exercises are delayed if any of the specified mission functions are not combat ready. Information on the duration of an exercise and the period during which rescheduling may be attempted is contained in the Employment Schedule (card type 90).

EXER NO. (50)	The sequential number of the exercise.
DESCRIPTION	A twenty-four character field which contains a description of the exercise. Any appropriate designation may be used.
WHEN DONE	Some exercises cannot be performed at night. A 9 in this column indicates daylight required. A 1 indicates that the exercise may be performed at any time.
COND. FOR MANNING	The basic readiness condition (I, III, IV or V) required to perform the exercise: 1 = I 2 = III 3 = IV 4 = V
AUG	If the basic readiness condition is to be augmented such as I-AAW, the number

of the augmented condition is entered in AUG. Up to five different augmentations are possible and these are defined by the user.

#### REQUIRED MISSION FUNCTIONS

Any one or all of up to twenty mission functions may be required to perform the exercise. A 1 in the appropriate column would indicate that the mission function is required.

# SHIP SIMULATION MODEL INPUT

**NAVAL PERSONNEL RESEARCH AND DEVELOPMENT LABORATORY**

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[illegible]



## 15. TOTAL SHIP READINESS SCORING

### CARD TYPE 60 contains

the information used to establish the overall readiness rating of the ship. Four ship readiness states C1 (Fully Combat Ready), C2 (Combat Ready, C3 (Marginally Combat Ready) and C4 (Not Combat Ready) are defined in terms of the readiness states of the basic mission functions (subsystems). This information is used during the program to continuously evaluate the readiness of the total ship, which can be affected any time the readiness of a mission function changes.

COND NO. (500 including card type 61)	The sequential number of the readiness scoring condition.
READINESS RATING	The readiness rating which corresponds to the states of the mission functions.
REQUIRED MINIMUM CONDITION OF THIS SUBSYSTEM FOR THIS RATING	Each of the subsystems defined as mission function, can be in any of the four readiness states. While it is possible to assume that the readiness of the ship is equal to the lowest readiness of any function, alternative interpretations are possible. Therefore the user enters in these columns the com- binations of readiness states which corres- pond to the overall ship readiness rating. The indicator D/C (Don't Care) is provided for those instances where the loss of one mission function (C4) may preclude the use of others and therefore their state is of no interest.

# SHIP SIMULATION MODEL INPUT

## NAVAL PERSONNEL RESEARCH AND DEVELOPMENT LABORATORY

COND NO	READ- INESS RATING	REQUIRED MINIMUM CONDITION OF THIS SUBSYSTEM FOR THIS RATING																				CARD TYPE
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	
1	1	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	60
2	2	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	60
3	3	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	60
4	4	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	60

## 16. MISSION FUNCTION READINESS SCORING

### CARD TYPE 61

contains the information necessary to establish the readiness scoring of the individual mission-oriented functions (also referred to as subsystems). The readiness score of a mission function is completely determined by the user by identifying the readiness score (C1, C2, C3, or C4) which is associated with a given combination of up/down states of the equipment which comprise the mission function.

SUBSYS. NO.	The number of the subsystem (mission function) which is being scored. This number must correspond with the numbering scheme used in card type 30.
NO. EQUIP. ITEMS	The number of equipment items in the subsystem which will be used to score the function.
COND NO. (500 including card type 60)	A sequential listing of the readiness score entries. Numbering starts over with each subsystem.
READINESS RATING	The readiness score of the subsystem which corresponds to the equipment states defined to the right.
REQUIRED CONDITION OF THIS EQUIPMENT FOR THIS RATING	Three states may be defined for each equipment G (Good), B (Bad) or X (Don't Care). Each equipment item must have one of these three designations.

**NOTE:** While the number of possible up/down state combinations is very large, the number of probable combinations, based on equipment failure rate, is significantly less. For purposes of the present effort, the expected availability of equipment was used to reduce the entries in the decision table to a reasonable number

[illegible]

## 17. EMPLOYMENT SCHEDULE

CARD TYPE 90 contains a sequential listing of commands which constitute the mission scenario. Special commands are also provided for ordering output reports during the simulation. Each command is associated with a time of execution which corresponds with the time of simulation.

DEPART	Puts ship to sea at condition IV steaming. Establishes mission termination time and assigns name to mission for all output.
PORT (50)	Puts ship into port at designated time and stays there until SEA command causes it to leave.
SEA (50)	Takes ship out of port at designated time. While ship is at sea, training exercises can be assigned, readiness conditions can be imposed, and evolution can occur.
TRAINEX NO (500 including "EVOLUTE")	Causes the identified training exercise to be assigned within the designated period for the specified duration. Its performance is a function of the required equipment state which may cause delay.
EVOLUTE NO (500 including "TRAINEX")	Causes the identified evolution to be assigned for the designated period.
ACTION POSSIBLE (100 including "ACTION IMMINENT")	Imposes readiness condition III on the ship for the specified duration while the ship is at sea. When the period ends, the ship returns to condition IV steaming.

**ACTION IMMINENT**  
(100 including  
"ACTION  
POSSIBLE")

Imposes readiness condition I on the ship for the specified duration while the ship is at sea. When the period ends, the ship returns to condition IV steaming.

**PRINT OUTPUT**

Causes a full set of output reports to be printed starting at the designated time and continuing to print another full set at the specified interval.

**PRINT SNAPSHOT**

Causes a snapshot to be printed at the designated interval, starting at the specified time.

**ANCHORS AWEIGH**

Denotes the end of all the data and the start of computation.

# SHIP SIMULATION MODEL INPUT

NAVAL PERSONNEL RESEARCH AND DEVELOPMENT LABORATORY

EMPLOYMENT SCHEDULE													CARD TYPE																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																									
COMMAND	AT		UNTIL		DURATION OR OUTPUT FREQ (HOURS)	MISSION NAME																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																
	TIME	DAY	TIME	DAY			51	52	53	54	55	56		57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																	
DEPART	0	0	0	0	366	0	SHAKE DOWN	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																	
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## APPENDIX B

### SHIP II OUTPUT REPORTS

#### A. Description of Heading Information

Each of the nine types of reports to be described contain an identical heading. The heading contains information about the study being run and the time at which the report was generated. The mission name is an identifying term input to the model by the user. Day NO identifies the time in days within the simulation run at which the report was output. Normally Ship II output reports are generated every seven days. Subsequent reports would therefore be generated on days 14, 21, 28, etc. Time (hrs) also identifies the time within the simulation run at which the report was generated, except that time is presented in hours rather than days. Time of day represents the time of day at which the report was generated. The output report examples given later contain a value of zero for time of day. This value represents time 0000 on a 24 hour clock. Day of week is simply the day of week at which the report was generated. The report interval, day of week and time of day are determined by the user and input to the model as part of the Employment Schedule. The last item of the heading is the division number and name, both of which are specified by the user and are part of the input data.

#### B. Discussion of Output Reports

The following sections contain a brief explanation of each SHIP II Output report. An example of the output report follows each discussion.

##### 1. Personnel Record

This report summarizes the workload for each crewman. The first seven columns are identifying information which is taken from model input data. The information in the following ten columns represents hours worked in each of nine task categories and total hours worked. The last column (labeled NWW) is the percent of standard Navy work week which is based on the total hours worked for each man. The model calculates this percentage based on a 74 hour workweek for watchstanders and a 66 hour workweek for non-watchstanders.

The information in each column is totaled for the



total divisions and for watchstanders and non-watchstanders separately. The personnel record also accumulates data for the total ship (not shown), when more than one division is used. In this case a separate page is allotted to each division.

Abbreviations:

Watch - Watch hours  
RTRA - Readiness training  
EVOL - Evolutions  
PM - Planned maintenance  
CM - Corrective maintenance  
FM - Facilities maintenance  
S/A - Support and administrative  
SD - Service diversions  
NWW - Percent of standard Navy work week.

1 REEMAN NAISIAID  
NAISIAID ASV

B-3

## 2. Maintenance Personnel Summary-Rate/RTG

This report summarizes the performance of each type of maintenance personnel summarized by rate. The first two columns identify rate and rating. The column labeled "CAT" contains rating information coded as follows:

- 1 = Chief
- 2 = 1st class
- 3 = 2nd class
- 4 = 3rd class
- 5 = FN, SN, etc.
- 6 = XN
- 7 = FA, SA, etc.

The third column contains the number of each rate/rating combination used in the simulation.

The next two columns ("CM hrs/W" and "PM hrs/W") contain the total CM and PM hours for each class of personnel. The "total" column contains the sum of the PM and CM columns. The column labeled "NO QS" contains the number of times that a maintenance job was delayed while waiting for maintenance personnel of each rate/rating to become available for the job. The column labeled "Q HRS" contains the total time that corrective maintenance jobs were waiting for personnel to become available.

The column "NO INRPT" contains the number of times that planned and corrective maintenance jobs were interrupted to get a man of the rate/rating specified in columns 1 and 2.

### Abbreviations:

CAT = category  
NOB - number on board  
CM HRS/W = corrective maintenance hours/week  
PM HRS/W = planned maintenance hours/week  
NO QS = number of queues  
Q HRS = queue hours  
NO INRPT = number of interrupts

SHIP SIMULATION MODEL  
 NAVAL PERSONNEL RESEARCH AND DEVELOPMENT LABORATORY  
 \* \* \* MISSION NAME# STG STUDY RUN 1 6 MEN \* \* \*  
 \* \* \* TIME (HRS)= 168.02 DAY NO= 7 \* \* \*  
 \* \* \* TIME 24DAY= 0 DAY 8WEEK= MON \* \* \*  
 \* \* \* MAINTENANCE PERSONNEL SUMMARY RATE/RTG \* \* \*

NAIF	CAT	AGR	CM	HRS/W	PM	HRS/W	TOTAL	NO QS	Q HRS	NO INRPT
000	2	1	0.00	7.57	0.00	0.00	7.57	0.00	0.00	0.00
000	4	2	19.76	17.53	1.00	3.97	37.29	1.00	3.97	0.00
01	1	1	9.88	0.00	0.00	0.00	9.88	0.00	0.00	0.00
01	2	2	0.00	1.40	0.00	0.00	1.40	0.00	0.00	0.00
010	3	3	0.00	3.84	0.00	0.00	3.84	0.00	0.00	0.00
010	4	3	0.00	12.25	0.00	0.00	12.25	0.00	0.00	0.00
010	5	6	6.16	12.53	0.00	0.00	12.49	0.00	0.00	0.00
10	3	1	3.00	1.00	0.00	0.00	1.00	0.00	0.00	0.00
20	3	1	3.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
00	3	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ALL						3.97		1.00		

### 3. Maintenance Personnel Summary-NEC

This report is identical to the preceding report except that personnel are specified by NEC.

S H I F      S I M U L A T I O N      M O D E L  
 NAVAL PERSONNEL RESEARCH AND DEVELOPMENT LABORATORY  
 \* \* \* MISSION NAME# STG STUDY RUN 1 6 MEN \* \* \*  
 \* \* \* TIME (HRS)# 168.02 DAY NO# 7 \* \* \*  
 \* \* \* TIME 3#DAY# 0 DAY 8#WEEK# MON \* \* \*  
 \* \* \* MAINTENANCE PERSONNEL SUMMARY \* NEC \* \* \*

NEC	AGR	CM	HRS/W	FM	HRS/W	TOTAL	NO OS	Q HRS	NO INRPT
480	1		9.88		0.00	9.88	0.00	0.00	0.00
481	2		0.00		0.00	0.00	0.00	0.00	0.00
482	2		0.00		0.00	0.00	0.00	0.00	0.00
891	3		0.00		0.00	0.00	0.00	0.00	0.00
ALL									

#### 4. Equipment Summary

The first three columns contain identifying information from model input data; the first two specify the subsystem number and equipment number within the subsystem. The equipment name is in the third column. The next column "OP T" specifies the total number of hours (since the last set of output reports) for which the equipment was operating properly. "DOWN T" contains the total hours during which the equipment was malfunctioning. The next column contains the availability percent - the percentage of the time since the last output that the equipment was operating properly.

The number of equipment failures is listed in the next column, followed by the total time for detection of failures. The column labeled "Defers" contains the total time for which equipment waited to be repaired because of deferrals for parts and/or assistance.

The next four columns contain data on corrective maintenance performance for each equipment. The columns labeled "TS Q" and "REP Q" contain the total number of queue hours for troubleshooting and repair, respectively. These queues are caused by unavailability of personnel, parts, or equipment. The columns labeled "TS TIF" and "REP TIF" contain the total time spent in the troubleshooting and repair functions for each equipment.

The next column contains the actual and apparent status of equipment. The right hand half of the column contains the apparent current status of the equipment and the left hand side contains the actual equipment status. Usually actual and apparent status will be the same. However, when certain types of troubleshooting and repair errors (see Section III-B) are simulated, actual and apparent status will differ after the error has occurred. These errors usually result in good apparent condition and bad actual condition.

The column labeled "TECS" contains the time in hours from the start of the simulation when the equipment entered the condition shown in the status column.

##### Abbreviations:

SS = Subsystem number  
EQP = Equipment number  
OP T = Operating time  
DOWN T = Down time (time during which the equipment was not operating)  
AVL PCT = Availability percent

FAIL = Number of failures  
DET T = Detection time  
DEFERS = Deferral hours  
TS Q = Troubleshooting queues hours  
TS TIF = Troubleshooting time in function  
REP Q = Repair queue hours  
REP TIF = Repair time in function  
TECS = Time entered current function

The abbreviations used in equipment names are standard Navy abbreviations.



SHIP SIMULATION MODEL  
 NAVAL PERSONNEL RESEARCH AND DEVELOPMENT LABORATORY  
 • • • MISSION NAME: STG STUDY RUN 1 A MEN • • •  
 • • • TIME (HRS): 168.02 DAY NO: 7 • • •  
 • • • TIME (HRS): 0 DAY 8 WEEK: MON • • •  
 • • • EQUIPMENT: SUMMARY • • •

SS EDP	NAME	EP T	DOWN T	AVL FCT FAIL	DET T	DEFERS	TS 0	TS TIF	REP Q	REP TIF	STATUS	TRCS
1	1 SLAF CM CSP UN1	167.89	0.00	100.00	0	0.00	0.00	0.00	0.00	0.00	READGOOD	0.00
1	2 A-SCAN CASL UN2	167.89	0.00	100.00	0	0.00	0.00	0.00	0.00	0.00	READGOOD	0.00
1	3 TGT TRCK CAS UN3	167.89	0.00	100.00	0	0.00	0.00	0.00	0.00	0.00	READGOOD	0.00
1	4 A-SCAN CAS UN4	167.89	0.00	100.00	0	0.00	0.00	0.00	0.00	0.00	READGOOD	0.00
1	5 SEGU TMR UN1	167.89	0.00	100.00	0	0.00	0.00	0.00	0.00	0.00	READGOOD	0.00
1	6 SAR XMITR UN1	167.89	0.00	100.00	0	0.00	0.00	0.00	0.00	0.00	READGOOD	0.00
1	7 SAR XMITR UN1	167.89	0.00	100.00	0	0.00	0.00	0.00	0.00	0.00	READGOOD	0.00
1	8 SAR XMITR UN1	167.89	0.00	100.00	0	0.00	0.00	0.00	0.00	0.00	READGOOD	0.00
1	9 SAR XMITR UN1	167.89	0.00	100.00	0	0.00	0.00	0.00	0.00	0.00	READGOOD	0.00
1	10 CTRL XMITR UN1	167.89	0.00	100.00	0	0.00	0.00	0.00	0.00	0.00	READGOOD	0.00
1	11 XCVR SHTC UN1	167.89	0.00	100.00	0	0.00	0.00	0.00	0.00	0.00	READGOOD	0.00
1	12 CAT XMITR UN1	167.89	0.00	100.00	0	0.00	0.00	0.00	0.00	0.00	READGOOD	0.00
1	13 ALDIE MATR UN1	167.89	0.00	100.00	0	0.00	0.00	0.00	0.00	0.00	READGOOD	0.00
1	14 FLT LFC MATR UN1	167.89	0.00	100.00	0	0.00	0.00	0.00	0.00	0.00	READGOOD	0.00
1	15 A-SCAN CAS UN1	167.89	0.00	100.00	0	0.00	0.00	0.00	0.00	0.00	READGOOD	0.00
1	16 DISTIB HX UN1	167.89	0.00	100.00	0	0.00	0.00	0.00	0.00	0.00	READGOOD	0.00
1	17 SAR XELCER UN1	167.89	0.00	100.00	0	0.00	0.00	0.00	0.00	0.00	READGOOD	0.00
1	18 SAR SCAR HEDUN2	167.89	0.00	100.00	0	0.00	0.00	0.00	0.00	0.00	READGOOD	0.00
1	19 SAR AMF HEDUN2	167.89	0.00	100.00	0	0.00	0.00	0.00	0.00	0.00	READGOOD	0.00
1	20 SAR AMF SCAR UN2	167.89	0.00	100.00	0	0.00	0.00	0.00	0.00	0.00	READGOOD	0.00
1	21 CATL GENV UN2	167.89	0.00	100.00	0	0.00	0.00	0.00	0.00	0.00	READGOOD	0.00
1	22 PLS SLP GEN UN2	167.89	0.00	100.00	0	0.00	0.00	0.00	0.00	0.00	READGOOD	0.00
1	23 SAR SIG CM UN2	167.89	0.00	100.00	0	0.00	0.00	0.00	0.00	0.00	READGOOD	0.00
1	24 SAR SIG CP UN2	167.89	0.00	100.00	0	0.00	0.00	0.00	0.00	0.00	READGOOD	0.00
1	25 SAR STFCN XF 2F	167.89	0.00	100.00	0	0.00	0.00	0.00	0.00	0.00	READGOOD	0.00
1	26 INEIC P-L LV125	167.89	0.00	100.00	0	0.00	0.00	0.00	0.00	0.00	READGOOD	0.00
1	27 FLT LFC IND UN3	167.89	0.00	100.00	0	0.00	0.00	0.00	0.00	0.00	READGOOD	0.00
1	28 B-SCAN RTCP UN3	167.89	0.00	100.00	0	0.00	0.00	0.00	0.00	0.00	READGOOD	0.00
1	29 SAR SCAR UN3	167.89	0.00	100.00	0	0.00	0.00	0.00	0.00	0.00	READGOOD	0.00
1	30 SAR MCNTH UN3	167.89	0.00	100.00	0	0.00	0.00	0.00	0.00	0.00	READGOOD	0.00
1	31 SAR TGT SIG UN3	167.89	0.00	100.00	0	0.00	0.00	0.00	0.00	0.00	READGOOD	0.00
1	32 SCN GENV SH UN3	167.89	0.00	100.00	0	0.00	0.00	0.00	0.00	0.00	READGOOD	0.00
1	33 BRN6 RG MEN UN3	167.89	0.00	100.00	0	0.00	0.00	0.00	0.00	0.00	READGOOD	0.00
1	34 PEAR SFLY ASS 41	167.89	0.00	100.00	0	0.00	0.00	0.00	0.00	0.00	READGOOD	0.00
1	35 TESTSET XPPD 42	167.89	0.00	100.00	0	0.00	0.00	0.00	0.00	0.00	READGOOD	0.00
1	36 RCP SH CASL UN4	167.89	0.00	100.00	0	0.00	0.00	0.00	0.00	0.00	READGOOD	0.00
2	1 ALL FR PRAP UN1	167.89	0.00	100.00	0	0.00	0.00	0.00	0.00	0.00	READGOOD	0.00
2	2 AZIM RCOR UN3	167.89	0.00	100.00	0	0.00	0.00	0.00	0.00	0.00	READGOOD	0.00
2	1 STAT/PERMIS PNL	167.89	0.00	100.00	0	0.00	0.00	0.00	0.00	0.00	READGOOD	0.00
2	2 STAT/PERMIS PNL	167.89	0.00	100.00	0	0.00	0.00	0.00	0.00	0.00	READGOOD	0.00
2	3 CPA CENTRAL CONS	167.89	0.00	100.00	0	0.00	0.00	0.00	0.00	0.00	READGOOD	0.00
2	4 REP SETTING EG	167.89	0.00	100.00	0	0.00	0.00	0.00	0.00	0.00	READGOOD	0.00
2	5 TPC SETTING EG	167.89	0.00	100.00	0	0.00	0.00	0.00	0.00	0.00	READGOOD	0.00
2	6 SCAR UN3	167.89	0.00	100.00	0	0.00	0.00	0.00	0.00	0.00	READGOOD	0.00

SHIP SIMULATION MODEL  
 NAVAL PERSONNEL RESEARCH AND DEVELOPMENT LABORATORY  
 \*\*\* MISSION NAME: STG STUDY RUN 16 MEN \*\*\*  
 \*\*\* TIME (HRS): 168.02 DAY NO: 7 \*\*\*  
 \*\*\* TIME OF DAY: 0 DAY OF WEEK: MON \*\*\*  
 \*\*\* EQUIPMENT SUMMARY \*\*\*

SS EOP	NAME	GP T	DOWN T	AVL PCT	FAIL	DET T	DEFERS	TS Q	TS TIF	REP Q	REP TIF	STATUS	TECS
4	3 LEADSPKR	167.89	0.00	100.00	0	0.00	0.00	0.00	0.00	0.00	0.00	GOOD	0.00
4	4 LEADSPKR WIDE RG	167.89	0.00	100.00	0	0.00	0.00	0.00	0.00	0.00	0.00	GOOD	0.00
4	5 CARLE	167.89	0.00	100.00	0	0.00	0.00	0.00	0.00	0.00	0.00	GOOD	0.00
5	1 SLESFC TGT SIM 1	167.89	0.00	100.00	0	0.00	0.00	0.00	0.00	0.00	0.00	GOOD	0.00
5	2 SLESFC TGT SIM 2	167.89	0.00	100.00	0	0.00	0.00	0.00	0.00	0.00	0.00	GOOD	0.00
6	1 CTR STA UNIT1	167.89	0.00	100.00	0	0.00	0.00	0.00	0.00	0.00	0.00	GOOD	0.00
6	2 REP CS UNIT2	167.89	0.00	100.00	0	0.00	0.00	0.00	0.00	0.00	0.00	GOOD	0.00
6	3 REP CS UNIT2	167.89	0.00	100.00	0	0.00	0.00	0.00	0.00	0.00	0.00	GOOD	0.00
6	4 XTRNRCVR UNIT3	167.89	0.00	100.00	0	0.00	0.00	0.00	0.00	0.00	0.00	GOOD	0.00
6	5 LS FR XDUCR T232	167.89	0.00	100.00	0	0.00	0.00	0.00	0.00	0.00	0.00	GOOD	0.00
6	6 LS FR XDUCR T232	167.89	0.00	100.00	0	0.00	0.00	0.00	0.00	0.00	0.00	GOOD	0.00
6	7 HI FR XDUCR T232	167.89	0.00	100.00	0	0.00	0.00	0.00	0.00	0.00	0.00	GOOD	0.00
6	8 HI FR XDUCR	167.89	0.00	100.00	0	0.00	0.00	0.00	0.00	0.00	0.00	GOOD	0.00
7	1 SENAR RECEIVER	167.89	0.00	100.00	0	0.00	0.00	0.00	0.00	0.00	0.00	GOOD	0.00
8	1 LCP STD PK107/2	167.89	0.00	100.00	0	0.00	0.00	0.00	0.00	0.00	0.00	GOOD	0.00
8	2 MSL LCH CARMK7/2	167.89	0.00	100.00	0	0.00	0.00	0.00	0.00	0.00	0.00	GOOD	0.00
8	3 ELEV PAR CR 62/2	167.89	0.00	100.00	0	0.00	0.00	0.00	0.00	0.00	0.00	GOOD	0.00
8	4 TRA PAR CR 61/1	167.89	0.00	100.00	0	0.00	0.00	0.00	0.00	0.00	0.00	GOOD	0.00
8	5 GLDG PK7 M0D1	167.89	0.00	100.00	0	0.00	0.00	0.00	0.00	0.00	0.00	GOOD	0.00
8	6 LCP CP CENT PNL	167.89	0.00	100.00	0	0.00	0.00	0.00	0.00	0.00	0.00	GOOD	0.00
8	7 ERR REC PK12M0D1	153.00	14.89	91.13	1	0.02	0.00	0.00	0.00	3.97	9.89	GOOD	135.89
8	8 DUMP DIR PK6/1	167.89	0.00	100.00	0	0.00	0.00	0.00	0.00	0.00	0.00	GOOD	0.00
9	1 TFRP LC TR M2/0	167.89	0.00	100.00	0	0.00	0.00	0.00	0.00	0.00	0.00	GOOD	0.00
9	2 TFRP LC TR M2/0	167.89	0.00	100.00	0	0.00	0.00	0.00	0.00	0.00	0.00	GOOD	0.00
9	3 TAST/CHK SPARES	167.89	0.00	100.00	0	0.00	0.00	0.00	0.00	0.00	0.00	GOOD	0.00
9	4 SP TGLS / ACCES	167.89	0.00	100.00	0	0.00	0.00	0.00	0.00	0.00	0.00	GOOD	0.00
10	1 RPTGIF CNTRL UN1	119.52	0.00	100.00	0	0.00	0.00	0.00	0.00	0.00	0.00	GOOD	0.00
10	2 ELECTR CNSL UN2	119.52	0.00	100.00	0	0.00	0.00	0.00	0.00	0.00	0.00	GOOD	0.00
10	3 MACH UN3	119.52	0.00	100.00	0	0.00	0.00	0.00	0.00	0.00	0.00	GOOD	0.00
10	4 METER CONTROLLER	119.52	0.00	100.00	0	0.00	0.00	0.00	0.00	0.00	0.00	GOOD	0.00
10	5 TWR CABLE UN4	119.52	0.00	100.00	0	0.00	0.00	0.00	0.00	0.00	0.00	GOOD	0.00
10	6 TWR CABLE UN4	119.52	0.00	100.00	0	0.00	0.00	0.00	0.00	0.00	0.00	GOOD	0.00
10	7 ACEU PRJ TP1 UN5	41.88	0.00	100.00	0	0.00	0.00	0.00	0.00	0.00	0.00	GOOD	0.00
10	8 ACEU PRJ TP1 UN5	41.88	0.00	100.00	0	0.00	0.00	0.00	0.00	0.00	0.00	GOOD	0.00
10	9 ACEU PRJ TP2 UN5	41.88	0.00	100.00	0	0.00	0.00	0.00	0.00	0.00	0.00	GOOD	0.00
10	10 ACEU PRJ TP2 UN5	41.88	0.00	100.00	0	0.00	0.00	0.00	0.00	0.00	0.00	GOOD	0.00
10	11 CRAX SACH BX UN6	167.89	0.00	100.00	0	0.00	0.00	0.00	0.00	0.00	0.00	GOOD	0.00
10	12 TEXT LEAD UN7	167.89	0.00	100.00	0	0.00	0.00	0.00	0.00	0.00	0.00	GOOD	0.00
10	13 TEXT LEAD UN8	167.89	0.00	100.00	0	0.00	0.00	0.00	0.00	0.00	0.00	GOOD	0.00
10	14 TEXT LEAD UN9	167.89	0.00	100.00	0	0.00	0.00	0.00	0.00	0.00	0.00	GOOD	0.00
10	15 CPL A1 1267705-1	167.89	0.00	100.00	0	0.00	0.00	0.00	0.00	0.00	0.00	GOOD	0.00
10	16 CPL A2 1267706-1	167.89	0.00	100.00	0	0.00	0.00	0.00	0.00	0.00	0.00	GOOD	0.00
10	17 CPL A3 1267707-1	167.89	0.00	100.00	0	0.00	0.00	0.00	0.00	0.00	0.00	GOOD	0.00
10	18 CPL A4 1267708-1	167.89	0.00	100.00	0	0.00	0.00	0.00	0.00	0.00	0.00	GOOD	0.00
10	19 CPL A5 1267709-1	119.52	0.00	100.00	0	0.00	0.00	0.00	0.00	0.00	0.00	GOOD	0.00
10	20 CPL A6 1267709-1	119.52	0.00	100.00	0	0.00	0.00	0.00	0.00	0.00	0.00	GOOD	0.00

SHIP SIMULATION MODEL  
 NAVAL PERSONNEL RESEARCH AND DEVELOPMENT LABORATORY  
 MISSION NAME: STG STUDY RUN 1 A MEN  
 TIME (HRS): 168.02 DAY NO: 7  
 TIME 30 DAY: 0 DAY 0 WEEK: MON  
 EQUIPMENT SUMMARY

SS EOP	NAME	GP T	DOWN T	AVL PCT	FAIL	DET T	DEFFRS	TS O	TS TIF	REP O	REP TIF	STATUS
10 21	CBL #7 1267713-1	119.52	0.00	100.00	0	0.00	0.00	0.00	0.00	0.00	0.00	GOOD
10 22	CBL #8 1267713-1	119.52	0.00	100.00	0	0.00	0.00	0.00	0.00	0.00	0.00	GOOD
10 23	CBL #9 1267713-1	119.52	0.00	100.00	0	0.00	0.00	0.00	0.00	0.00	0.00	GOOD
10 24	ELEC/ACCY PARTS	119.52	0.00	100.00	0	0.00	0.00	0.00	0.00	0.00	0.00	GOOD
10 25	W/ACH REP PARTS	119.52	0.00	100.00	0	0.00	0.00	0.00	0.00	0.00	0.00	GOOD
11 1	RECORDER MK 2XBT	167.55	0.34	99.80	1	0.18	0.00	0.00	0.00	0.00	0.14	GOOD
11 2	PREPES T-4 XBR	167.89	0.00	100.00	0	0.00	0.00	0.00	0.00	0.00	0.00	GOOD
11 3	LAUNCH STATION	167.89	0.00	100.00	0	0.00	0.00	0.00	0.00	0.00	0.00	GOOD
TOTAL		15.23								3.97		
MEAN								0.00				0.04

## 5. Planned Maintenance Summary

A separate planned maintenance summary is output for each PM task frequency (daily, weekly, monthly, quarterly, semi-annual and annual). An example of a report of each type is included. Note that the format is identical for each type of report.

The first two columns contain subsystem and equipment numbers taken from input data. The third column contains the PM task number. Each PM task is given a separate task number by the user and comprises part of the PM input data.

The fourth column specifies the task frequency, using the following code: D = daily, W = weekly, M = monthly, Q = quarterly, S = semi-annual, and A = annual. This information is also taken from input data.

The information in the next five columns is generated by the simulation. The column labeled "sched" contains the number of times the PM task was scheduled. The next two columns tell the frequency with which the task was delayed and cancelled. The column labeled "FAILS FND" contains the number of times that an equipment failure was found during PM. The last column contains the total manhours spent on each PM task.

A sum of the entries in the last five columns for all PM tasks of each type is given on the last line of each report. The line containing these sums is identified by a zero in the "FREQ" column..

### Abbreviations:

SS = Subsystem number  
EQP = Equipment number  
NO = PM task number  
FREQ = Interval of performance  
SCHED = Number of times the task was scheduled  
DELAYED = Number of times the task was delayed  
CANCELLED = Number of times the task was cancelled  
FAILS FND = Failures found  
TOT MHRS = Total manhours

SHIP SIMULAT ION MODEL  
 NAVAL PERSONNEL RESEARCH AND DEVELOPMENT LABORATORY  
 . . . MISSION NAME: STG STUDY RUN 1 6 MEN . . .  
 . . . TIME (HRS): 168.02 DAY NR: 7 . . .  
 . . . TIME 3 DAY: 0 DAY 6 WEEK: MON . . .  
 . . . PLANNED MAINTENANCE SUMMARY . . .

SS	ECP	AG	FREQ	SCHED	DELAYED	CANCELLED	FAILS	FND	TOT	MHRS
1	14	1	D	7	2	0	0	0	1.35	
3	3	2	D	7	7	0	0	0	6.94	
3	3	3	D	7	12	1	0	0	6.09	
8	3	4	D	7	2	0	0	0	2.09	
8	6	0	D	28	23	1	0	0	16.47	

SHIP SIMULATION MODEL  
 NAVAL PERSONNEL RESEARCH AND DEVELOPMENT LABORATORY  
 \*\*\* MISSION NAME# STG STUDY RUN 1 6 MEN \*\*\*  
 \*\*\* TIME (HRS)= 168.02 DAY NO= 7 \*\*\*  
 \*\*\* TIME 30 DAY= 0 DAY 6 WEEK= MON \*\*\*  
 \*\*\* PLANNED MAINTENANCE SUMMARY \*\*\*

SS	ECR	NG	FREQ	SCHED	DELAYED	CANCELLED	FAILS	FND	TOT	MHRS
1	19	5	M	1	0	0	0	0	0	0.29
1	12	6	M	1	13	0	0	0	0	3.09
1	1	7	M	1	0	0	0	0	0	1.04
1	1	8	M	1	0	0	0	0	0	0.80
1	1	9	M	1	0	0	0	0	0	0.58
1	1	10	M	1	2	0	0	0	0	2.80
1	1	11	M	1	1	0	0	0	0	1.00
1	1	12	M	1	1	0	0	0	0	0.98
1	1	13	M	1	4	0	0	0	0	1.50
1	1	14	M	1	5	0	0	0	0	1.38
1	1	15	M	1	1	0	0	0	0	0.62
1	1	16	M	1	2	0	0	0	0	8.94
1	1	17	M	1	1	0	0	0	0	0.98
1	1	18	M	1	0	0	0	0	0	0.98
1	1	19	M	1	0	0	0	0	0	0.22
1	1	20	M	1	0	0	0	0	0	0.39
1	1	21	M	1	5	0	0	0	0	0.00
1	1	22	M	1	0	0	0	0	0	0.40
1	1	23	M	1	2	0	0	0	0	0.31
1	1	24	M	1	0	0	0	0	0	0.98
1	1	25	M	1	3	0	0	0	0	0.40
1	1	26	M	1	1	0	0	0	0	0.61
1	1	27	M	1	2	0	0	0	0	0.29
1	1	28	M	1	26	0	0	0	0	0.00
1	1	29	M	1	1	0	0	0	0	1.18
1	1	30	M	1	1	0	0	0	0	2.00
1	1	31	M	1	2	0	0	0	0	0.19
1	1	32	M	1	9	0	0	0	0	3.00
1	1	33	M	1	3	0	0	0	0	0.58
1	1	34	M	1	142	0	0	0	0	35.53
1	1	35	M	29						

[illegible]

SHIP SIMULATION MODEL  
 NAVAL PERSONNEL RESEARCH AND DEVELOPMENT LABORATORY  
 \* \* \* MISSION NAME: STG STUDY RUN 1 6 MEN \* \* \*  
 \* \* \* TIME (HRS): 168.02 DAY NO: 7 \* \* \*  
 \* \* \* TIME 3xDAY: 0 DAY 8xWEEK: MON \* \* \*  
 \* \* \* PLANNED MAINTENANCE SUMMARY \* \* \*

SS	EQP	AG	FREQ	SCHED	DELAYED	CANCELLED	FAILS	FND	TOT	MHRS
1	20	59	0	1	1	0	0	0	0	0.49
8	22	60	0	0	0	0	0	0	0	0.00
2	22	61	0	0	0	0	0	0	0	0.00
9	22	62	0	0	0	0	0	0	0	0.00
8	22	63	0	0	0	0	0	0	0	0.00
2	22	64	0	0	0	0	0	0	0	0.00
2	22	65	0	0	0	0	0	0	0	0.00
3	22	66	0	0	0	0	0	0	0	0.00
3	22	67	0	0	0	0	0	0	0	0.00
3	22	68	0	0	0	0	0	0	0	0.00
9	22	69	0	0	0	0	0	0	0	0.00
9	22	70	0	0	0	0	0	0	0	0.00
3	22	71	0	0	0	0	0	0	0	0.00
3	22	72	0	0	0	0	0	0	0	0.00
3	22	73	0	0	0	0	0	0	0	0.00
3	22	74	0	0	0	0	0	0	0	0.00
4	22	75	0	0	0	0	0	0	0	0.00
8	22	76	0	0	0	0	0	0	0	0.00
7	22	77	0	0	0	0	0	0	0	0.00
8	22	78	0	0	0	0	0	0	0	0.00
8	22	79	0	0	0	0	0	0	0	0.00
8	22	80	0	0	0	0	0	0	0	0.49



SHIP SIMULATION MODEL  
 NAVAL PERSONNEL RESEARCH AND DEVELOPMENT LABORATORY  
 . . . MISSION NAME: STG STUDY RUN 1 6 MEN . . .  
 . . . TIME (HRS): 168.02 DAY NO: 7 . . .  
 . . . TIME @ DAY: 0 DAY @ WEEK: MON . . .  
 . . . PLANNED MAINTENANCE SUMMARY . . .

SS	ECP	AGE	FREQ	SCHED	DELAYED	CANCELLED	FAILS	FND	TOT	MMRS
11	1	79	S	0	0	0	0	0	0.00	
0	2	80	S	0	0	0	0	0	0.00	
1	11	81	S	0	0	0	0	0	0.00	
3	1	82	S	0	0	0	0	0	0.00	
3	2	83	S	0	0	0	0	0	0.00	
3	2	84	S	0	0	0	0	0	0.00	
3	2	85	S	0	0	0	0	0	0.00	
3	2	86	S	0	0	0	0	0	0.00	
3	2	87	S	0	0	0	0	0	0.00	
3	3	88	S	0	0	0	0	0	0.00	
3	5	89	S	0	0	0	0	0	0.00	
3	3	90	S	0	0	0	0	0	0.00	
3	6	91	S	0	0	0	0	0	0.00	
3	3	92	S	0	0	0	0	0	0.00	
6	5	93	S	0	0	0	0	0	0.00	
6	4	94	S	0	0	0	0	0	0.00	
9	6	95	S	0	0	0	0	0	0.00	
7	1	96	S	0	0	0	0	0	0.00	
7	1	97	S	0	0	0	0	0	0.00	
7	1	0	S	0	0	0	0	0	0.00	

S H I F      S I M U L A T I O N      M O D E L  
 NAVAL PERSONNEL RESEARCH AND DEVELOPMENT LABORATORY  
 • • • MISSION NAME#    STG STUDY RUN 1 6 MEN • • •  
 • • • TIME (HRS)#    168.02    DAY NO#    7 • • •  
 • • • TIME 0#DAY#    0    DAY 0#WEEK# MON • • •  
 • • • PLANNED MAINTENANCE SUMMARY • • •

SS	EQP	NG	FREQ	SCHEN	DELAYED	CANCELLED	FAILS	FND	TOT	MHRS
11	3	98	A	0	0	0	0	0	0	0.00
18	7	99	A	0	0	0	0	0	0	0.00
1	1	100	A	0	0	0	0	0	0	0.00
1	17	101	A	0	0	0	0	0	0	0.00
1	17	102	A	0	0	0	0	0	0	0.00
2	2	103	A	0	0	0	0	0	0	0.00
8	6	104	A	0	0	0	0	0	0	0.00
1	11	105	A	0	0	0	0	0	0	0.00
1	11	106	A	0	0	0	0	0	0	0.00
6	6	107	A	0	0	0	0	0	0	0.00
1	12	108	A	0	0	0	0	0	0	0.00
1	12	109	A	0	0	0	0	0	0	0.00
3	2	110	A	0	0	0	0	0	0	0.00
3	3	111	A	0	0	0	0	0	0	0.00
3	3	112	A	0	0	0	0	0	0	0.00
4	1	113	A	0	0	0	0	0	0	0.00
4	1	113	A	0	0	0	0	0	0	0.00
0	0	0	A	63	178	1	0	0	0	55.92

## 6. Facilities Maintenance Summary

The first four columns contain identifying information taken from input data. The first column contains the individual job number; the second column contains the division assignment; only personnel from the assigned division will be used for FM tasks. A zero in the division column indicates a job not assigned to any particular division.<sup>1</sup> In the third column a description of the job can be included if desired. The fourth column identifies the job as either FM or S/A.

The last five columns contain simulation output. The first of these, "MHRS/D" tells how many manhours per day were scheduled for each job. The next column contains the number of times that each job was scheduled in the reporting period. The column labeled "HRS LEFT" contains the total number of man hours scheduled but not done. The following column contains the number of days on which the job was scheduled but not accomplished. The information in the last column tells the total number of times a job was started but interrupted by a higher priority task before it could be completed.

After each job has been listed, a summary by division and total ship is provided. The first line which has no entry in the "JOB" column is the start of this summary. This line will have a "0" in the division column and contains a total for all jobs not assigned a specific division responsibility. Following this will be a total for each division listed by division number. The last line will have "99" in the division column, which identifies the total ship summary of data.

### Abbreviations:

JOB = FM-S/A job number  
DIV = Division  
MHRS/D = Man hours scheduled per day  
NO SCHED = Number scheduled  
HRS LEFT = Hours left

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<sup>1</sup>The output report example was taken from a study using only one division.

SHIP SIMULATION MODEL  
 NAVAL PERSONNEL RESEARCH AND DEVELOPMENT LABORATORY  
 MISSION NAME: STG STUDY RUN 16 MEN  
 TIME (HRS): 168.02 DAY NO: 7  
 TIME 32DAY: 0 DAY 02WEEK: MON  
 FACILITIES MAINTENANCE \* SUPPORT/ADMIN

JOB DIV	DESCRIPTION	TY	MHRS/D	NO SCHED	HRS LEFT	DAYS LEFT	INTERPTS
1	1	FM	9.79	14.00	0.00	0.00	8.00
2	1	FM	2.17	7.00	0.00	0.00	1.00
3	1	SA	0.51	5.00	0.51	0.06	0.00
4	1	SA	0.51	6.00	0.00	0.00	0.00
5	1	SA	0.41	6.00	0.00	0.00	0.00
6	1	SA	0.17	6.00	0.00	0.00	0.00
7	1	SA	0.18	6.00	0.00	0.00	0.00
8	1	SA	1.79	6.00	0.00	0.00	0.00
9	1	SA	0.34	6.00	0.00	0.00	0.00
10	1	SA	0.35	5.00	0.35	0.04	0.00
11	1	SA	3.75	8.00	0.00	0.00	2.00
	0		0.00	0.00	0.00	0.00	0.00
	1		16.97	75.00	0.86	0.11	11.00
	2		0.00	0.00	0.00	0.00	0.00
99			16.97	75.00	0.86	0.11	11.00

## 7. Division Training Summary

The first two columns of this summary contain the division number and name. The third column contains the minimum attendance necessary for a class to be held; this value is taken from input data. The next column contains the total number of different men who have attended a division training class. The column labeled "total hrs" contains the total number of class hours (not man hours in class). The last three columns contain the total number of class sessions which occurred, the average attendance, and the average class duration.

SHIP SIMULATION MODEL  
 NAVAL PERSONNEL RESEARCH AND DEVELOPMENT LABORATORY  
 . . . MISSION NAME: STG STUDY RUN 1 6 MEN . . .  
 . . . TIME (HRS): 168.02 DAY NO: 7 . . .  
 . . . TIME @ DAY: 0 DAY @ WEEK: MON . . .  
 . . . DIVISIONAL TRAINING . . .

NO	DESCRIPTION	RQD	ATTEND	TOTAL	MEN	TOTAL	HRS	NO	SESSNS	AVG	ATTEN	AVG	DURAT
1	ASW DIVISION	2	4095	53	0	7.17	8	6.63	0.90				
2						0.00	0	0.00	0.00				

## 8. Training Readiness Summary

The first two columns contain the number and name of each training exercise. The next four columns contain the number of times each exercise was scheduled, performed, cancelled and delayed. The last two columns contain number of delays and total delay hours for those delays caused by a required equipment being unavailable.

The last row on the report (identified by a zero in the "NO" column) contains a total of the entries in the last six columns.

### Abbreviations:

SS DELAYS = Subsystem delays  
DELAY HRS = Delay hours

S H I P      S I M U L A T I O N      M O D E L  
 NAVAL PERSONNEL RESEARCH AND DEVELOPMENT LABORATORY  
 . . . MISSION NAME: STC STUDY RUN 1 6 MEN . . .  
 . . . TIME (HRS): 168.02      DAY NO: 7 . . .  
 . . . TIME 02DAY: 0      DAY 02WEEK: MON . . .  
 . . . TRAINING READINESS SUMMARY . . .

SCHEDULED PERFORMED CANCELLED ALL DELAY SS DELAYS DELAY HRS				
3	3	0	0	0.00
3	3	0	0	0.00
0	0	0	0	0.00
0	0	0	0	0.00
0	0	0	0	0.00
6	6	0	0	0.00

E X E R C I S E  
 ASW GENERAL CLANKERS  
 OTHER GENERAL CLANKERS  
 Z-16-L ARTY SHOOT  
 Z-17-L ASREC SHOOT  
 SURFACE ACTION

NO 1  
 2  
 3  
 4  
 5  
 0



## 9. Readiness Summary

This report summarizes the readiness condition of all the subsystems listed in column two of the report. The only subsystems which are listed in column two are those designated by the user as subsystems whose correct performance is necessary for the total ship to accomplish its mission.

The main body of the table shows for each subsystem the number of times that the subsystem was in each readiness status, the total hours in each status, the average hours in each status and the percent of total time in each status. The abbreviations C-1, C-2, C-3, and C-4 represent the standard Navy readiness status designations. The column labeled "current" contains the readiness status of each subsystem at the time of the report. The last column contains the time at which the current status was entered, measured in hours from the start of the simulation run.

After all subsystems have been listed, the report summarizes the readiness status of the total ship. The relationship between subsystem readiness and total ship readiness is specified by the user. However, Ship II currently uses only subsystem state of mission-related subsystems to calculate total ship readiness status.

### Abbreviations:

TECS = Time entered current function

NO SURSYSTEM  
1 AN/SCS-26CX ACT  
2 AN/SCS-26CX PASS  
3 MK116 LFCS  
6 MCC-2 GERTRUDE  
7 UGN-4 EPTH RC/FR  
8 MK 16 ASROC LACH  
9 MK 32 AWT WG/LG  
10 NIXIE TERPEDO CH

B-27

SHIP SIMULATION MODEL  
 NAVAL PERSONNEL RESEARCH AND DEVELOPMENT LABORATORY  
 MISSION NAME: STG STUDY RUN 16 MEN  
 TIME (HRS): 168.02 DAY NO: 7  
 TIME 3-DAY: 0 DAY 8 WEEK: MON  
 READ INESS SUMMARY

NO SUBSYSTEM  
 11 BT LAUNCHER TUBE

	C-1	C-2	C-3	C-4	CURRENT	TECS
TIMES AT STATUS	2	0	0	1	C-1	27.67
HOURS AT STATUS	167.67	0.00	0.00	0.34		
AVER HOURS AT STATUS	83.84	0.00	0.00	0.34		
PCENT TIME AT STATUS	99.80	0.00	0.00	0.20		
TIMES AT STATUS	1	0	0	1	C-4	27.33
HOURS AT STATUS	27.33	0.00	0.00	140.69		
AVER HOURS AT STATUS	27.33	0.00	0.00	140.69		
PCENT TIME AT STATUS	16.27	0.00	0.00	83.74		

TOTAL SHIP